Citizen Science In Conservation Biology: Best Practices in the GeoWeb Era

by

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Abstract

Conservation biology emerged as an activist discipline in the 1980s in response to increasing evidence that Earth is undergoing a biodiversity crisis. Building on foundations of biological science and applied resource management methods, this new discipline called upon its practitioners to both undertake scientific research to improve understanding of all species and ecosystems, and to take social and political action to protect and enhance endangered biodiversity. In the current era of declining budgets for biodiversity research and management, volunteer citizen science is gaining recognition as an important strategy for expanding and extending the work of embattled professional conservation biologists. New technologies such as handheld computers, GPS, GIS, interactive map services, and the internet, and the wide-spread availability, adoption and adaptation of these technologies by the general public, have created an environment where citizens can be rapidly mobilized to gather, process, and communicate data in support of conservation biology's twin goals.

In this thesis I explore citizen science within conservation biology and within the concept of the GeoWeb. I trace the history of citizen science in biology since the late 1800s to the current day, to better understand the practice and its contribution to conservation science. I find that citizen science is often employed to undertake research at large spatial scales, and that often location is a key attribute of the data citizens gather; as a result, the infrastructure and methods of the GeoWeb are fundamental to many citizen science projects.

In the spirit of conservation biology, I pair my research of citizen science with the assembly of a set of best practices for increasing the impact of the practice on the conservation agenda, and then evaluate twelve current citizen science projects currently underway in British Columbia against these practices. I conclude that citizen participation in biological science furthers both of conservation biology's goals: it both increases our body of knowledge about biodiversity, and helps to develop an informed and empowered constituency for conservation action and ecologically sustainable stewardship.

“We assume implicitly that wounds inflicted by ignorant humans and destructive technologies can be treated by wiser humans and wholesome technologies”

Michael E. Soule (1987), pg 4

“We shape our tools and afterwards our tools shape us”

Marshall McLuhan (1964), pg 8

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Chapter 1. Introduction

I begin with three assumptions. First, I take as a given that biodiversity is important, and that the biodiversity crisis we see today has been largely caused by human actions and will require political will and social engagement, as well as science-based plans and actions, to resolve. I also find that there is ample evidence we live in an era of shrinking government funding for professional scientists within government agencies in Canada (The Canadian Press 2012, Duck 2012, Langer 2012, Fitzpatrick 2011, Leahy 2011) and abroad (including cuts to the US EPA (Efstathiou 2011) and the UK's DEFRA (Jowit 2010)). Finally, there is evidence that the protected area system alone is insufficient to ensure biodiversity protection (Chan *et al.* 2011). These three assumptions all point to the need for the conservation of biodiversity to be part of the everyday life of society as a whole. If the biodiversity crisis is to be averted or at least mitigated, then more citizens must step up their involvement: we can't rely on the professional scientists and land managers to do all the heavy lifting. As well as becoming more aware of, and reducing, our ecological footprint (Rees 1992), we must help to form the questions and assemble the evidence needed to better understand and then manage the living world in its vast diversity and complexity. This leads me to conclude that we need citizens to become effectively involved in the science of conservation biology.

Conservation biology is a young science: it emerged as a "mission-orientated discipline" (Soule 1985) in the 1980's, and the Society for Conservation Biology (SCB) was established in 1985[1]. The early membership of the society was characterized as "students, scientists, managers, and administrators" and the "unique responsibilities" of the society included research, communication of results, and extension activities. The core values of the Society remain the same. Yet much has changed in the last 35 years: for instance, concepts that were new in the 1980's, like biological diversity and population research using DNA, have since become the norm. Technology has progressed dramatically: in the information technology sector, the desktop computer had only just been invented in 1985, and now more than 80% of the population carries a smartphone with many more applications and capabilities than those early PCs and Macintosh personal computers. Canadian society has undergone many changes in this

[1] See Meine *et al.* 2006 for a history of the first 20 years of the SCB.

time as well; for instance, the population is becoming increasingly urbanized and comfortable with digital technologies. In regards to nature and society, there seems to be a disconnect between social values and government funding; for although the environment is often a top priority for Canadians, and conservation of biodiversity is now a standard goal in resource management, funding for this work is in decline at the national level and in many provinces (Fitzpatrick 2011, Leahy 2011).

The SCB was built on a foundation of academic sciences and resource management practice: its goals were (and are) to affect positive conservation results through science, policy, and practice. Meine *et al.* (2006) found that one of the novel characteristics of the field was its recognition of “the “close linkage” between conservation and economic development” (pg 640) and the related emergence of the concept of sustainability. The SCB realized that “To achieve its goals, conservation biology had to reach beyond its base in the sciences and generate conversations with economists, educators, ethicists, advocates, policy makers, the private sector, and community-based conservationists” (*ibid.*).

These conversations between scientists, social scientists, humanists, and the community-based activists in turn built on Aldo Leopold’s Ecological-Evolutionary Land Ethic (Leopold 1949) and data gathering collaborations between biologists and the public which dated back to at least the late 1900’s. In 1995 the Cornell Laboratory for Ornithology (CLO)’s Rick Bonney coined the term “citizen science” to describe the experience in ornithology, where projects such as the Christmas Bird Count (CBC) had teamed professionals up with curious citizens in order to record early winter bird observations across large spatial scales (Bonney 2007). The activist attitude of conservation biology urges us to go beyond mere theories and the data collection and analysis that support or contradict theories, however: “Success will be measured by the degree to which we can integrate scientific understanding into our community life, by the effectiveness of our approaches to sustaining the diversity of life and the health of ecosystems, and by respect for the living world we are able to foster within our varied cultures and within the human heart” (Meine *et al.*2006*:*646).

In this thesis, therefore, I argue that citizen scientists contribute most to conservation biology when their contributions to science support their contribution to the development of an ecologically sustainable society. In conservation science, citizens aid the identification of important research questions and then play a key role in data collection and / or processing.

Furthermore, by becoming involved in science, citizens gain knowledge, skill, understanding, and increase their esteem in the eyes of professional scientists and managers: this makes them more effective agents for positive conservation actions and decisions, including decisions taken by themselves (to reduce their ecological footprint) and their leaders (to increase species and ecosystem protection and reduce or mitigate ecological impacts). As conservation biology is an activist science by definition, the essential goal of the discipline is furthered only when scientific discovery advances action within policy, management, and footprint impacts. Through learning and applying the tools of science, the citizens transform themselves into more active participants in ecologically sustainable development.

As previously stated, citizen science has a long history in conservation: in the US, the first volunteer migratory bird surveys occurred in the late 1880s (Bonney *et al*. 2009a), predating the foundation of the Society for Conservation Biology by 100 years. Citizen science is now experiencing exuberant growth and has captured the imagination of many researchers: one author (Silvertown 2009) heralds a new dawn for citizen science, while others (DeVictor *et al*. 2010) suggest this new era will exist in a time beyond scarcity. Major centres for the understanding, analysis, and support for citizen science research are emerging at Cornell University, Colorado State University, and, in Canada, through the GEOIDE network in the Participatory GeoWeb for Engaging the Public on Global Environmental Change project (Sieber *et al*. 2012).

The rapid pace of current and expected citizen science expansion is due, in large part, to technological innovations in computers, databases, and information and communications technology (ICT) infrastructure, and social innovations in how people inhabit this digital realm (i.e., Web 2.0). The expansion of activity in this space is also due to other societal shifts, such as: a newfound respect for citizen science and the data that it produces in mainstream science (Bhattacharjee 2005); growing public interest in, and demand for, participation in planning and management (Jamieson *et al*. 1999; Conrad and Hilchey 2011); and the shrinking government commitments to in-house research and monitoring that I've already noted.

We have, then, a serious problem --the biodiversity crisis--and some elements of a solution: the rise of conservation biology as a distinct discipline and an increase in citizen involvement and effectiveness in conservation science and management. To better understand the role of citizen science in conservation biology today, I investigate the state of the art of the practice. These best practices are disaggregated into a five component parts[2] and then synthesized and organized into the form of an abstract ideal model for an effective citizen science project. I then evaluate twelve current projects against this 'gold standard'. In this way I attempt to both advance the scientific contributions of citizens, and also to provide some direction for improving their activism. My thesis as a whole thus reflects my thesis statement that, in order to be effective, citizen science must contribute to both science and sustainability.

In this thesis I will have a particular focus on projects which make use of the internet for volunteer collection, management, or communication of data that is geospatially-enabled. I will argue that making scientifically credible information and state of the art data management tools available and freely accessible via the internet can increase the involvement of citizens, including increasing the amount of data voluntarily collected and contributed, and heightening the sense of personal or community empowerment required to take action on conservation issues.

One might wonder why *geospatial* data is central here. Biology (including ecology) and taxonomy sciences at all structural levels, from the gene to the species, population, and ecosystem, are clearly fundamental to biodiversity conservation. The importance of geography to conservation biology may be less obvious to some; but, as ecology investigates the distribution and abundance of species across space, geographical science plays a leading role. Meine *et al.* (2006) identifies GIS as an innovative technology used by conservation biologists, beginning in the 1980s, "to develop creative means of synthesizing data sets, communicating that information, and applying it to conservation planning" (*ibid*: 642). The location of species observations is usually a key data attribute. The investigation of the effect of spatial structure of populations or spatial features such as corridors, fragmentation and isolation date back to the first volume of the Journal of Conservation Biology (Simberloff and Cox 1997, Noss 1997, Quinn and Hastings 1997). Geography's rich visual language provides a powerful tool for information processing and communication as well: map-making is a cornerstone of public participation in science, planning, and management, for it provides a framework for conceptualizing spatial patterns and relations. The maps created in public processes are also typically included as figures or appendices in resulting publications because they are uniquely capable of concisely

[2] I choose five as the number for this disaggregation arbitrarily. The typologies of citizen science which I review in chapter two all were equally arbitrary in their use of three types: it seems that using relatively small prime numbers is a common disaggregation practice. Using low numbers reduces complexity and may improve the memorability of a set of concepts.

conveying spatial information. Geographical considerations, methods, and representations are therefore typically part of the design, data capture protocols, and the published results of ecological investigations that in turn provide the empirical foundation for conservation plans.

1.1. Outline

In chapter two I review the literature, define citizen science, and briefly describe the history of the practice within conservation biology, and provide reasons for the recent rapid growth. I will draw from the literature review to describe in some detail the current state of citizen science, and the main contributions to science, policy, and management. Citizen science is now recognized to encompass some variations, and recent papers investigating different dimensions of these variations are discussed. I will show that citizen science exists primarily in relation to science and scientists: the practice extends the scientific enterprise out from the university and institutional centres into the wider community, but, at its core, it usually requires scientists to provide leadership and structure in order for it to be effective. However, there are some examples of scientists working to devolve this leadership role to citizens and communities by providing web-based tools and resources, and thereby improving the conditions for independent grass-roots efforts to contribute to evidence-based planning and management. There is also recognition that these web applications should be designed with a user-centred focus in order to increase their accessibility, educational value, and usefulness for the volunteers. Other empowering aspects of the websites for many projects are an open data philosophy (often including downloadable data as well as browse-able data such as interactive web maps) and reports of how collected information has been interpreted and used for conservation action and advocacy. I also show that although there are some great examples of citizen science for some species, especially birds, the coverage of volunteer projects varies greatly across space and across the biodiversity spectrum.

In chapter three I attempt to distil the broad field of conservation citizen science activities into an idealized and defined set of best practices--including recommended methods. I decided to disaggregate citizen science in conservation biology into five broad domains: 1) project direction and management; 2) protocol development; 3) volunteer recruitment, training, retention, and calibration; 4) data management and analysis; and 5) communications and publications. I found this disaggregation captured the breadth of the general subject while allowing more careful consideration of the component parts. These five domains or components are discussed and summarized at the end of the chapter.

In chapter four, I take a detailed look at twelve citizen conservation science projects British Columbians have participated in, in order to gain more insight into how these projects function within the province's physical and cultural domains, and also to provide constructive criticism that could be used to improve the conservation impact. Although not a complete list of projects in the province, these projects represent the bulk of volunteer biodiversity research and monitoring in BC today and so provide a reasonably comprehensive gauge of the effectiveness and limits of this work. In each case, I dissect the project based on the five broad domains described above in order to evaluate the relation between these projects and my ideal citizen science model as defined in chapter two. As in the review of literature as a whole, bird projects dominate citizen science in BC.

Chapters two through four illustrate the potential for, and limitations of, citizen science and its contribution to conservation biology as a whole. Findings and recommendations are then summarized in chapter five. My key finding is that although citizen science is already contributing significantly to conservation biology, professional guidance is required to ensure the work is effective for science-based management of a wider range of biodiversity. This leads to suggestions for further study.

Chapter 2. Citizen Science: Definitions, Evolution, and Current Status

2.1. Research Methods

In order to cast a wide net for my review of the literature and assessment of best practices, I began with a search of Geobase (Elsevier 2012) through UBC's Library system to develop an initial list of papers and Google searches to track down citizen science projects; these were followed-up with direct contact via email with authors and project coordinators to get up-to-date information. The initial Geobase search, using the keywords "Citizen" AND "Science" AND "Conservation" uncovered 156 records published in or before 2010. Included in these records were survey papers by Silvertown (2009) and Devictor *et al*. (2010) which listed 23 and 22 projects respectively: of these 45 projects, 44 had websites. To find out more about project persistence, these 44 sites were then checked to see if they were still live. Although some website URLs had changed, 42 of the 44 sites were still in operation in October, 2011. Requests for more information were sent to contacts specified on these 42 sites; this resulted in the discovery of additional papers, including several from 2011.

Articles and other material from the database and online searches, from project websites, and received through follow-up email were used to define citizen science and to determine the dimensions and contributions of the practice in conservation biology today. For the most part, the papers and the projects they describe consider citizen science primarily within Canada, the USA, Europe, Australia and New Zealand. Some projects such as eBird (Sullivan *et al*. 2009) do extend into Latin America, and Dunn and Weston's (2008) global review of Bird Atlases provides a partial picture of activities elsewhere. It was not possible to determine if the fact that the searches were done in English using American (Google, Geobase) tools limited the results in this way, or whether citizen science actually has a distribution similar to the distribution of English language speakers. Interestingly, the geography of citizen science (at least according to Bonney, 2007) seems to match the geography of conservation biology: Meine *et al.* (2006: 632) discuss the history of the discipline "through the lens of North American institutions, individuals, and experiences" and raise the question if the field as it is could only have emerged here. Greenwood's (2007) history of amateur contributions to ornithology and bird conservation in

Europe mirrors the North American experience, however, and although conservation biology did not originate there, the related discipline of landscape ecology did (Troll 1939 in Wu 1996).

2.2. Definitions: What is a Citizen Scientist? What is Citizen Science?

The term "citizen scientists" was coined by Rick Bonney in 1995 to describe participants in the Cornell Laboratory for Ornithology (CLO)'s growing number of "scientist-driven research projects" (Bonney 2007 in Bonney *et al.* 2009a: 15). Since that time a range of definitions for this term has emerged. A citizen scientist was defined by Jonathon Silvertown (2009: 467) as "a volunteer who collects and/or processes data as part of a scientific enquiry." Cooper *et al.* (2007, online) defined citizen science as "a method of integrating public outreach and scientific data collection locally, regionally, and across large geographic scales." Other authors have offered slight variations on this theme, including Lepczyk *et al.* (2009: 308) who found that definitions converged on "the involvement of citizens from the non-scientific community in academic research." In a recent review of citizen science in biogeography, Devictor *et al.* (2010) stated that citizen science is particularly important in addressing research questions that span large spatial or temporal dimensions.

In the ecological literature[3], then, the concept of citizen scientist has emerged recently from science and exists in relation to traditional expert-lead science. Citizen scientists benefit science by providing resources to the scientist or scientists leading the research, including: inexpensive and (to varying degrees) skilled labour for data collecting and / or processing, equipment, and even funds. In return, citizen scientists learn about science by participating in it directly. Bonney *et al.* (2009) list the potential educational impacts of public participation in citizen science: developing understanding and knowledge; enhancing engagement or interest; improving skills; changing attitudes; and changing behaviour. Citizen science may also provide an opportunity for citizens to shape science by directing research towards the issues that they care about. Educating the public through their participation in citizen science is considered to be an excellent way to further the stewardship goals of conservation biology, for as citizens become more involved in conservation science, they learn ways to reduce or mitigate human impacts on other species and assist in ecosystem and species recovery (Bonney *et al.* 2007). The

[3] It should be noted that citizen science also exists within other fields such as climate science (e.g. Skeptical Scientist www.skepticalscience.com accessed 12 April 2013); however, a review of these projects is outside the scope of this paper.

scientific ecological knowledge citizens gain through working as volunteers on these projects also improves their credibility with the authorities responsible for conservation actions in government agencies; these authorities are then more willing to involve the citizens in conservation planning and management decision-making (Jamieson *et al*. 1999). Social capital is increased when people become empowered in this way; this can lead to improved community sustainability.

Lepczyk *et al.* (2009) point out that as well as educating and training citizens to work with scientists and technocrats, citizen science also provides opportunities for scientists to work with the public. This extension work brings scientific understanding from the world of the academic (the so-called ivory tower) to the larger population, increasing the democratic pressure for evidence-based planning and management by decision-makers. Linkages between scientific thought, the wider population, and decision-makers are required in order to make the leap from conservation discovery to a sustainable conservation action plan that is well-supported by the community at large.

Greenwood's study of citizen science in ornithology (Greenwood 2007), particularly in the UK, illustrates the many contributions to conservation science and policy that the volunteer birders have made over the last 150 years. Volunteers, or amateurs, as Greenwood usually calls "the people who contribute to ornithological science for the love of it, not for payment" (2007: S78), often have significant field experience observing birds and many also have received scientific or technical training in other disciplines. In many cases, professional scientists followed the lead of amateur ornithologists who first developed field study techniques, including methods for ring-banding, atlasing, and continual monitoring, that later became widespread; authored or co-authored many papers; and served as chairs on various conservation committees. Bonney *et al.* (2009a) provide a similar account of amateur contributions in the US. In ornithology, at least, the professional – amateur dichotomy may in reality be better understood as a partnership or continuum.

In the case of birds, citizen scientists' data is valuable to scientists because it is plentiful, extends over large spatial and temporal scales, and because it measures a number of demographic variables. Data quality is addressed, primarily by collaborating scientists, through study design, including formal standardized protocols, data filtering, and large sample sizes. As many bird species are relatively easy to identify and people have long been drawn to birds[4], assuring data quality and quantity poses less problems than with some other taxa (e.g. insects and plants). Some ornithological projects are designed as longitudinal studies with long time lines, such as the annual Christmas Bird Count (CBC), in its 111th year in 2012, while others are planned to occur over a limited time period, for instance for tracking the rapid dispersal of a disease or of radiation contamination across space, or to measure environmental conditions in specific locations. In each case, a protocol or method for data collection is developed. After development and testing, volunteers are taught how to employ this protocol, and, in some cases, a sample of volunteer data is used to calibrate the entire set of data collected through a comparison with expert data. As well as the what, where, and when data of the observation itself, many studies capture auxiliary information such as effort (e.g. person-time spent searching) that can be used to standardize data. Data filtering can include self-filtering by volunteers (e.g. level of certainty); quizzing volunteers before and after training; automated filtering by an expert model (for instance, flagging rare, new, or unlikely species observations); and, in some cases, by field confirmation. Many projects require user registration for people wishing to provide data; this can also be used to filter the data or to recognize top, or novel, data contributors as part of a volunteer recruitment or retention strategy. Large sample sizes allow precise parameter estimation and thus reduce uncertainty and increase the usability of research findings for evidence-based decision-making. Modern computing systems enable rapid data processing and analysis: early projects used paper forms or cards and, due to the huge volume of volunteered returns, in some cases analysis was impossible.[5]

As well as data quality control, data analysis remains primarily in the professional scientist's domain. The literature documents the evolution of ever-more complex statistical methods used to analyze data, build population models, and test new hypotheses about species distributions (including the location and timing of breeding and migration), abundance, mortality, survival, habitat associations, and reproduction. Computers, databases, and ICTs that

[4] The webpage for the Birds & People book project, a partnership between BirdLife international, a British NGO, and author Mark Cocker, states that birds have played a role in human society since the Neolithic age and represented central deities in ancient Greek, Roman, and Aztec cultures (see http://www.birdsandpeople.org/main.htm accessed 7 March 2013)

[5] Cooke, the pioneer of requesting volunteer migratory bird observations, had collected 600,000 data cards by 1910: Greenwood (2007) relates unpublished correspondence with Erica Dunn that suggests that even today it would take 1-3 years to computerize these cards (which are now held by the USGS).

provides the technological foundation for these contemporary analysis methods have also added complexity to analysis processes (Michener and Jones 2012).

Although Greenwood's account of amateur ornithology provides many examples of citizen science emerging without professional involvement in the past, the high standards for data quality and the complexity of data management and analysis discussed above create barriers to the amateur scientist today. Newman *et al.* (2011) provides more reasons why professional involvement is now required in order for citizen science to be effective in conservation science and management, including: project oversight and coordination, protocol development and refinement, training, cyber-infrastructure (websites and online tools), and financial support. However, the emergence of volunteered geographic information (VGI) on the internet, which both benefits from and fosters spatial and ICT literacy in the population, may indeed herald a new era in citizen science. The CitSci project (www.citsci.org accessed 7 March 2013), the Citizen Science Central toolkit programme at CLO (www.birds.cornell.edu/citscitoolkit/ accessed 7 March 2013), iSpot (www.ispot.org.uk/ accessed 7 March 2013) , iNaturalist (www.inaturalist.org accessed 7 March 2013) and the indicia project (code.google.com/p/indicia/ accessed 7 March 2013) are all providing online tools to reduce technical and knowledge barriers for amateur and community-driven projects. Although these web-based projects are lead by scientists, the professional involvement is primarily technical, and project leadership and management may more easily be conducted by non-experts without compromising the value of the information thus produced.

Why do people volunteer their time and resources to citizen science projects? Some of the reasons found in the literature include: fun and enjoyment (Goffredo *et al*. 2010, Greenwood 2007, Dickenson *et al.* 2012), social benefits (Peers 1997, Dickenson *et al.* 2012), physical health (Peers 1997), a love of nature, an interest in natural history, a concern for natural places, threats facing species, populations, and ecosystems (Stoltmann 1987), and a desire to take action for positive change (Jamieson *et al.* 1999).

In summary, a conservation citizen science project is typically designed and managed by professional scientists who recruit volunteers to gather or process data to answer a research question. Due to the scale or nature of the question, large numbers of human observations or other human processes are required. The scientists leading the research develop a protocol for the volunteers to use in data capture or processing. Volunteers are recruited through communications strategies or retained through existing networks, and are provided some training and resources for data collection. Data quality is addressed by creating an appropriate data collection protocol and training volunteers to use it, by filtering or screening uploaded data before accepting it into the database, and by large sample sizes.

Citizen science contributes primarily to research within a specific discipline, such as in taxa-based projects (such as the CBC). Newman *et al.* (2010a) shows that citizen science also provides research opportunities in other areas, including GIScience. Table 1 is an adaptation of a table from Goodchild (2009) and shows some key GIScience questions and how citizen science research may advance them.

Table 1. Citizen science contributions to GIScience research questions

GIScience questions	**Citizen science contributions**
Representation	Formulate best practices for representing species locations on the Earth's surface from a citizen scientist perspective (Points)
Communication	Discover ways to better communicate the relationship between the representation (species location) and the user. [Use of a plus (+) to indicate more locations can be seen upon further zoom]
Visualization (display)	How do methods of display affect the interpretation of geographic data? How can the science of cartography be extended to take advantage of the power of the digital environment? What basic properties of display determine its success (Use cartographic symbols meaningful to citizen scientists such as flags for surveys)
Relationship between the representation and the user	How do people, rather than machines, think about the world? How can computer representations be made more like the ways people think? How do people reason with, learn about, and communicate their geographical world? (Volunteers think they found a species; they do not think that they 'made a visit to an area and detected a species occurrence')
Data quality	How to assess the accuracy and precision of a representation? How to measure its accuracy? How to measure what is missing, its uncertainty? How to express these measures in ways that are meaningful to the user? How to visualize them?
Data storage	How to best store geospatial information? (Use cached tiles generated on the fly as needed to allow users to customize their own cartographic representation)
Data models/structures	Store/retrieve representation efficiently (Use cached data not federated searches – see Graham et al. 2009)

Citizen science also improves understanding of the scientific method and scientific literacy. Citizen science provides an informal learning environment where participants learn specific scientific skills, such as how to collect accurate data, and more general ones, such as critical thinking and methods for scientific inquiry (Dickenson *et al.* 2012). This improves citizen effectiveness in conservation advocacy and activism through increased credibility and influence with policy and management agencies, improved connections with agencies and decision-makers, leadership development, and the identification of community and resource values (Whitelaw *et al.* 2003). This may also improve the likelihood that evidence-based decision-making is employed in non-conservation-related areas of planning and management as well (Bonney *et al*. 2009a). Through contact with nature, participants may develop an increased sense of connection with the natural world that could influence their attitude towards biodiversity conservation (Miller 2006). Participating in a group that is working closely together towards a particular goal, such as conservation, may also be transformative. Peers (2007) looked at the Pacific Streamkeepers as a case study in learning through collaboration within a "community of practice", and found that 88% of interviewees (n=15) reported learning was a major benefit of project participation. As participants learnt, their role within a project grew, and some moved towards leadership roles. 88% also reported that their reasons for participating in the project changed over time, which also indicates that they have been affected by project participation. This was largely due to the relationships they built with other participants and physical health, rather than changes in their scientific or conservation management understanding. However, participant learning varies from project to project and may depend on: degree and method of interaction with professionals; carefully designed activities and explicitly articulated project goals; and available tools and resources (such as web-based graphing and mapping tools) (Dickenson *et al.* 2012).

2.3. Brief History of Citizen Science in Conservation Biology

Two hundred years ago, there were few professional scientists (Greenwood 2007, Silvertown 2009): Charles Darwin, for instance, was not paid during his nearly five year voyage on the Beagle in the 1830's (Darwin 1846). Science became increasingly professionalized during the late 19th century (see for instance Waller 2001) and by the mid 20th century was primarily a professional domain. Although citizen scientists predated science as we know it today, many authors, especially in North America, date citizen science back to the first CBC, which was launched by ornithologist and early U.S. National Audubon Society member Frank Chapman in 1900 as a conservationist's alternative to the traditional U.S. Christmas Side Hunt (Audubon 2011). Droege (2007) describes predecessors from the late 1800s, including bird data collected by lighthouse keepers and the voluntary migratory bird surveys lead by Wells Cooke. Greenwood (2007) traces citizen science efforts even further back in Europe, to spring migrant counts in Finland dating back to 1749 and in Belgium to 1844. Over the years, the contribution of volunteers to conservation within ornithology alone is spectacular, as Greenwood's detailed description of the co-evolution of amateur and professional ornithology in the UK demonstrates with considerable evidence. One of the innovations of amateurs was ring-banding of birds to track them over the years: Greenwood refers to thousands of papers that have been published using data from ring-banded birds, much of it collected by volunteers. The British Trust for Ornithology (BTO), a non-governmental organization (NGO), where Greenwood works, publishes its own journal and staff members contribute to dozens of papers every year (www.bto.org). Across the Atlantic, the partnership between the National Audubon Society, another NGO, and the CLO has also been very productive: scientists have analysed data generated with significant volunteer effort, and published many articles on bird ecology, avian disease distribution, and related topics (Bonney *et al*. 2009b).

However, the perceived value of citizen science within the scientific establishment, at least in the US, has undergone a significant paradigm shift over the last decade or so. Even though many papers had been published on the CBC and the Breeding Bird Survey (BBS – lead by the United States Geological Survey (USGS) and Bird Studies Canada) in the scientific literature, much of mainstream science remained sceptical about the value of volunteer data collection (Drennan 1981, Darwall and Dulvy 1996, Foster-Smith and Evans, 2003). The value of CBC data has long been debated, for instance, with concerns raised about the lack of structural standardization, randomization, and expert observers (Hickey 1955, Bock and Root 1981, Dickenson and Bonney 2012). Through the years these concerns were addressed through a better understanding of the strengths and weaknesses of the CBC dataset (Bock and Root 1981), new statistical tools and methods (Bock and Ricklefs 1983, Sauer and Link 2002), cross referencing CBC and BBS data (Butcher 1990), and more creative analysis of effort (Peterson 1995, Link and Sauer 1999).

Early in the new millennium, when the CBC passed the 100 year mark, a ten member international expert panel was struck to conduct an independent review of the CBC and its scientific value, and, if possible, to recommend measures that could improve the scientific value of the survey without compromising the traditional educational and social values. The CBC Review Panel determined that significantly changing the protocol of the CBC could result in a decline of users and could also make the data incomparable with the 100-year dataset. On the other hand, modest changes to the survey, combined with cleaning up the historical database, implementing post hoc adjustments and state-of-the-art analyses (including GIS analyses), and improving data access, would significantly increase the value of the survey to science (Francis *et al.* 2004). The panel's findings were further described in a subsequent paper published in the journal The Auk (Dunn *et al.* 2005).

The review panel's work highlighted the value of the CBC data set, but the tide truly turned in favour of citizen science when one of the world's most prestigious journals, Science, published a story about citizen science and ornithology at Cornell University. Bhattacherjee (2005) describes the work led by the CLO that used volunteer observations of ill birds to build models of disease dispersal. This research received funding from a joint program of the U.S. National Institutes of Health and the U.S. National Science Foundation in 2000, in part because the volunteer data was, at last, considered reliable. That funding breakthrough made the story worth publishing in Science, which in turn furthered the respect given citizen science. By 2008, over 60 papers for the US Academy Ecology Society of America (ESA)'s annual meeting included the term citizen science in their abstract (Silvertown 2009), and a symposium was organized (Symposium 18: Citizen Science in Ecology: the Intersection of Research and Education. Lepczk *et al.* 2009). The contribution of citizen science to mainstream science had reached a new level.

Citizen science projects have also been shown to be policy-relevant: Baillie *et al.* (2006) provide two examples of citizen science results impacting farmland bird and avian flu policy in the UK, and the Pan-European Common Bird Monitoring program website (http://www.ebcc.info/pecbm.html) lists several examples of use of the program's information in policy development. Dunn & Weston's global survey of bird atlases (2008) also provides many examples of secondary studies that utilize volunteer-collected data.

2.4. Citizen Science in Conservation Biology Today

The field has now grown to the point that several authors, including Bonney *et al*. (2009a), Silvertown (2009), Haklay (2011), Conrad and Hilchey (2011), and Newman *et al.* (2011), have attempted to build typologies of citizen science. Silvertown grouped projects into three groups: those which were based on testing a hypothesis (the fewest examples); those which were primarily just for data collection; and those which provided tools for data collection and analysis. Haklay describes three types as well: the "classic" citizen science project, like the CBC, where a large, but widely distributed in space, network of observers follow a protocol to collect data as part of a hobby or recreational activity; projects within environmental justice campaigns, where data for negative environmental conditions such as air or noise pollution is collected to build a case for an intervention; and citizen cyberscience, which leverages personal computers, smartphones, and information and communication technologies (ICTs) to gather data. Conrad and Hilchey look at governance and participation within community-based management (CBM), which can be considered a form of citizen science, and find three types: consultative / functional (e.g. the CBC) where a central agency makes decisions and requests specific contributed information; collaborative, where volunteers participate on steering committees or other boards that make project decisions; and transformative, where volunteers create the project, often in a crisis situation with the goal of stimulating government action. The authors review a sample of citizen science projects and find some evidence that collaborative and transformative projects have the most success in establishing linkages with decision-making and therefore the most influence on conservation policy. Newman *et al.* use four categories that describe the role of the citizen in a science project: three as defined by Bonney *et al*. (contributory, collaborative, and co-created) and supportive.

Silvertown, Hacklay, Conrad and Hilchey, and Devictor *et al.* (2010) all provide lists of citizen scientist projects and their websites. Most of the examples are drawn from US and British sources, with Devictor *et al.* including some other European examples. Newman *et al.* also list many sites, and sites such as Citizen Science Central hosted by the Cornell Lab of Ornithology (http://www.birds.cornell.edu/citscitoolkit/projects/) and Scistarter (http://scistarter.com – formerly scienceforcitizens.net) are building databases of citizen science projects. Citizen Science Central's database includes around 250 projects, mostly from the USA (Shirk 2011). A review of all these sites is beyond the scope of this thesis; however, it is noteworthy that few Canadian projects are listed in the project registries at Citizen Science Central or Scistarter.

As well as papers describing and classifying the breadth of citizen science, there are now papers describing and analysing the extent of the practice. Two papers were found that conducted international evaluations of specific kinds of conservation citizen science. Schmeller *et al.* (2009) document the EuroMon project, which evaluated 395 volunteer biodiversity monitoring projects lead by 227 organizations in 28 countries across Europe between 2005 and September 2007. Dunn and Weston (2008) reviewed 272 bird atlases from around the world and found that most (82%) were from Europe and North America. Both papers provide strong support for the efforts of citizen scientists and their contributions to science and conservation management; as a result, it is worth taking a closer look at each of these in further detail. The implementation of conservation agreements by European nations has made biodiversity monitoring a requirement for all members. Schmeller *et al.*'s review of European biodiversity monitoring (EuroMon) projects (or "schemes" as they are called in Europe) used an online survey with 41 questions to collect data on 14 biodiversity-monitoring variables. These variables are reproduced in table 2, below.

Table 2. Variables describing biodiversity monitoring practices in EuroMon study

Variable	Abbreviation	Description
Annual frequency	ann. freq.	Between-year frequency of monitoring; 1, every year; 2, ever second year, etc.
Work effort	person-days	person-days/monitoring scheme
Work effort per species divided by the number of species monitored	person-days$_{spec}$	person-days/monitoring scheme
No. of professionals	N_{prof}	no. professionals in a scheme
No. of samples	$N_{samples}$	no. samples collected/visit
No. of sites	N_{sites}	no. sites visited
No. of species	$N_{species}$	no. species monitored simultaneously in a scheme
No. of visits	N_{visits}	no. visits per year
No. of volunteers	$N_{volunteers}$	no. volunteers in a scheme
Persons	$N_{persons}$	sum of volunteers and professionals in one scheme
Proportion of volunteers	%vol	proportion of volunteers in a scheme
Total costs	costs	sum of costs of equipment and salaries of professionals, as given by the average salary per country in 2005 (World Bank 2006).
Total costs per species	costs$_{spec}$	sum of costs of equipment and salaries of professionals, as given by the average salary per country in 2005 (World Bank 2006) divided by no. of species monitored in one scheme
Year	year	Start year of monitoring scheme

Next the authors conducted a principal component analysis in order to detect biodiversity monitoring differences between species groups and between nations. Only six species groups provided sufficient survey returns for statistical analysis (birds, n = 149; amphibians and reptiles, n = 53; mammals, n = 90; plants, n = 58; butterflies, n = 37; other insects, n = 31). Country-specific differences were determined for France (n = 91), Germany (n = 37), Hungary (n = 30), Lithuania (n = 32) and Poland (n =101). These countries were chosen based on survey responses and to enable comparison between eastern, ex-Soviet bloc nations and western European nations. They found that the main differences in monitoring practices for species groups was primarily due to differences in three variables: starting year, number of sites monitored, and proportion of volunteers to experts. They also found that costs were highest by species for mammal, amphibian, and reptile species; and that the highest project-wide costs were found in butterfly monitoring schemes due to the high number of monitoring stations (more that 50 on average). Volunteer recruitment and contributions had a geographic component: in Poland and Lithuania most monitoring work was done by professionals, while in France and Germany most was work was volunteered. The authors suggest that meeting biodiversity-monitoring goals in Western Europe more often requires volunteer involvement due to high professional salary costs. They were not able to determine whether lower volunteer recruitment in the ex-Soviet Bloc countries was due to reduced recruitment effort, difficulties in attracting volunteers due to traditional political culture, or "unclear political conditions in some countries" (*ibid*: 315).

A key finding was that, in general, sampling effort in a project increases with the number of volunteers: they found a strong positive relation between the number of observers and the number of sites monitored and number of visits per site. Since the standard error of a species' status estimate is negatively related to the total number of sampling units monitored per year, when compared to professional sampling methods, relatively large volunteer sampling efforts should counteract relatively higher observation errors, resulting in more precise estimates of a species' status in volunteered versus professionally collected datasets.

The global review of bird atlases (Dunn and Weston 2008) was undertaken with the general goal of exploring the application of information generated by these projects, and the specific goal of supporting the planning and implementation of *The New Atlas of Australian Birds*. The authors defined a bird atlas as "a project that conducts or collates (or both) surveys of bird presence or abundance that includes a spatial mapping component, and covers a significant geographical area, such as a county or local government area, state, province, country or continent" (*ibid*: 43). For the most part, the atlases Dunn and Weston uncovered in their review were hard copy atlases, as found in various libraries in Australia and, using search engines, via the web. Their review of the application of atlas data included a search of the literature and citations, and an examination of information collected by organizations such as the

British Trust for Ornithology (BTO) when sharing their atlas data with third parties (i.e. data sharing agreements).

Dunn and Westin found that most atlases involved volunteers (56.6% explicitly stated they were volunteer-based), and were run by ornithological societies (67.1% of the 143 atlases where this could be determined). Atlases varied hugely in spatial extent (from 21.5 km^2 to 10,390,000 km^2 – a factor of 480,000) and by number of observers that contributed (3 - 40,000), with more observers contributing to atlases covering more ground. Most of the atlas projects (78.3%) had published results in some form, and the authors found 97 scientific publications using data from five major atlases (covering Australia, South Africa, and Britain and Ireland), and an increasing number of publications over time for at least three of these. Bird distribution was the main topic covered in the publications (26.8%); however, there was also frequent use of these data in publications about ecology (20.6%) and land-use planning (17.5%). There was also significant use of these data in the non-academic sector of society, but (not surprisingly) examples of these uses were not well documented in the scientific literature. The authors offer a case study of requests to the *New Atlas of Australian Birds* by third parties; this example tracked the use of the data in environmental impact studies (49.3% of 793 requests came from environmental consultants), planning operations and regulatory processes (government departments placed 15.9%), other public interest (11% private individuals and 5.6% NGOs), as well as teaching, learning, and knowledge (universities, 14.2%). Dunn and Westin's paper thus traces volunteer data contributions to both scientific understanding and land use planning and management.

2.4.1. Growth Factors: Technology, Public Participation, Official Recognition

There are a number of factors that are working together to influence the current rapid growth of citizen science: some key ones include technological advances (Connors *et al*. 2012); social and political upheavals (Conrad and Hilchey 2009); and increasing recognition and acceptance of citizen science in science and evidence-based policy and planning (Bhattacherjee 2005, Schmeller *et al.* 2009, Newman *et al.* 2012)

Modern digital information systems, including database storage systems, software tools for statistical analysis and data visualization (including spatial dimensions), web social networking and communications software, office and mobile hardware (from laptops to smartphones), and ICT networks, have provided some big benefits to citizen science. Now vast amounts of data can be gathered quickly through standardized web forms, processed rapidly to explore patterns, and displayed interactively on web maps. Communications with volunteers and stakeholders is facilitated through content distributed freely over the web, and communications between volunteers as well as between volunteers and staff can be supported.

The ongoing expansion of ICT across space and culture creates a world of near ubiquitous digital communication and computation. This creates new opportunities and new platforms for citizen science, as many people now have personal computers or smartphones with many embedded instruments that can be used for scientific observations, including GPS, cameras, accelerometers, and wireless transmitters and receivers that can communicate with other devices such as radiation monitors or temperature sensors (Newman *et al.* 2012). Photographs in some storage formats can be automatically tagged with GPS data: as digital photos are now virtually free to produce and transmit, they have become a leading form of non-text data contributed to citizen science projects. Photos can also help with confirming species identification.

Social evolution, such as successful citizen-led efforts for environmental justice, the growth of public participation in planning, and the decline of government funding support for conservation staff in many jurisdictions, also plays a role in the growth in citizen science (Conrad and Hilchey 2011, Conrad and Daoust 2008). Citizen-lead projects are an example of bottom-up governance, where grass-roots involvement extends to all aspects of project decision-making. A well-known BC example of grass-roots citizen science was the work spearheaded by Randy Stoltmann of the Western Canada Wilderness Committee (WCWC) to locate the biggest specimens, either by volume or height, of BC native tree species as part of WCWC's campaigns to increase conservation of oldgrowth native forest. Stoltmann collected information about big trees from a number of sources and then endeavoured to visit, photograph, and measure the largest specimens. His work was documented in the *Hiking Guide to the Big Trees of Southwestern BC* (Stoltmann 1987). Many of the largest trees he identified were used by wilderness campaigners to help establish protected areas in BC. The BC forest service, in association with UBC's Department of Forestry, now maintains the BC Big Tree Registry that Stoltmann began in 1986. (http://bigtrees.forestry.ubc.ca/).

Participatory planning is now the norm throughout North America. People are motivated to volunteer their time to participate in public processes for many reasons, but many are drawn to conservation and environmental stewardship: as one indication of public participation in conservation, the US National Wildlife Federation listed 4200 organizations in 2009 (Newman *et al*., 2010b).

Cutbacks to government environmental monitoring and conservation departments are likewise widespread (The Canadian Press 2012, Duck 2012, Langer 2012, Fitzpatrick 2011, Leahy 2011, Efstathiou 2011, Jowit 2010, Conrad and Hilchey 2011, Conrad and Daoust 2008). In some cases, volunteers step in to continue projects when agency projects lose funding (Savan *et al.* 2003, Savan *et al*. 2004). One example is the transfer of Canada's NatureWatch program from an Environment Canada office to Nature Canada, an NGO. The free services that volunteers provide have an economic appeal to cash-strapped governments; yet so far, there has been little effort made to capture volunteer data by bureaucracies. And, as citizen science generally relies on professional science guidance, cutbacks to the professional conservation cadres increases the downside risk for ecological management.

The projects experts or authorities conduct are examples of top-down governance because volunteer participation is limited to providing data as requested by a central authority (for instance, the BTO, CLO, or the EMAN office). Scientists and governments have learned to see volunteer networks as a low cost way to collect meaningful data across large spatial and temporal scales. This is especially true in Europe and with birds. In BC, both the federal and provincial governments are actively supporting Bird Studies Canada's *BC Breeding Bird Atlas* and will use the resulting data and maps in various management and planning activities. The federal government is also involved in Whale Watch, the Pacific Shorekeepers, and the Community Mapping Network in BC. In each case, at both the provincial and federal level, partnerships with other organizations, including Bird Studies Canada (the leading national taxon-based society in Canada), community-based monitoring organizations (Shorekeepers, CMN), and the Vancouver Aquarium (Whale Watch), are essential to provide project resilience against risks posed by reduced government funding and technical support.

2.4.2. Citizen Science as a Class of Volunteered Geographic Information (VGI)

Michael Goodchild (2007) coined the phrase "Volunteered Geographic Information" – VGI – to describe the recently observed, and suddenly widespread, phenomena of people contributing spatial data to web sites, including OpenStreetMap (http://www.openstreetmap.org accessed 19 April 2013) and Wikimapia (http://www.wikimapia.org accessed 19 April 2013). VGI includes citizen science observations, reports of various dangers and hazards (such as wildfire or bear sightings), public consultation linked to specific places, dialogue about community resources such as local food sources, and various other georeferenced reports, descriptions, or even photographs and stories.

VGI, in turn, may be considered to be part of the public GeoWeb, which includes everything from government internet map services, to commercial applications such as Google Earth (http://www.earth.google.com accessed 19 April 2013) and Google Maps (http://www.maps.google.com accessed 19 April 2013), to location-based services using GPS in smartphones, to map mashups. Map mashups typically make use of data that could be georeferenced, such as addresses, from one website and display them using geographic data from another website[6]. One of the classic examples of a map mashup is Housingmaps (http://www.housingmaps.com accessed 19 April 2013), which takes housing data from craigslist (http://www.craigslist.org accessed 19 April 2013), geocodes the addresses, and shows the resulting points on a Google Map interface. The spectacular growth of the GeoWeb was triggered by the technology that made it possible for anyone with an internet connection to rapidly browse largely seamless place, transportation, remote sensor, and topographic data for the entire globe. Not satisfied with simply viewing geographic data provided by others, software developers and hackers soon found ways to display their own data as well, and Google and others wisely chose to support this tsunami of public interest through the development of application programming interfaces (APIs).

One of the main criticisms of GIS was that it was built by, and for, powerful entities within society, such as governments and large industry, and in many ways created an uneven playing field for people that held opposing views to these entities. Miller (2006) recounts some of the "GIS and society" debates of the 1990s, and the search for "GIS/2" – a rewired GIS that would enable and support a myriad of alternative representations, conceptions and perceptions about what the world is or could be. The fact that Google, one of the world's largest corporations by stock value, has provided the software platform that has enabled the rise of quick and easy critical geographic representation was an irony that was not lost on Miller.

An important research question for VGI revolves around the credibility of the data (Flanagin and Metzger 2008). Since anyone can create a Google Map or add points to Wikimapia, historical methods of providing credibility to information, such as the "stamp of

[6] For a more nuanced history and definition of map mashups see McConchie (2008).

approval" from an expert or authoritative source, are no longer valid; the vast amounts of VGI added daily to the internet make it impossible for experts to perform quality assurance on it. Flanagin and Metzger consider citizen science data to be a special class of VGI, however, since it retains some credentialization of the data observers (through training). One can go further than this: citizen science also retains other aspects of traditional authoritative credentialization including expert project management, scientific leadership, authoritative protocols, user accounts, filtering methods, and expert software designers and engineers, data gatekeepers and data managers. Citizen science data, especially of the ornithological variety, is relatively well understood, since it has long been used, evaluated, and analysed by scientists. It is possible that data quality lessons learnt in this field may have broader application within VGI. For example, the large sample size which contributes to reduced error in common bird data is analogous to the concept of "crowd-sourcing" in Wikimapia (like Wikipedia), where the large number of volunteers involved contributes to the data quality, suggesting that, to some degree, in VGI data quality and quantity are related.

2.4.3. Recruiting and Retaining Volunteers for Conservation Citizen Science

Volunteers are needed for all citizen science projects, often in large numbers and distributed across large areas, so strategies for recruiting and retaining volunteers are in many cases critical to project success. Scientists have employed a range of communication strategies to recruit volunteers, including: promoting projects to members of existing networks, especially naturalist groups and other environmental NGOs; outreach to schools, community groups, and professional associations ; press releases and media events or advertising through mass media; social media and websites; and the production of hard-copy promotional materials such as pamphlets and newsletters (Cooper *et al.* 2007, Greenwood 2007, Bonney *et al.* 2009a, Goffredo *et al.* 2010, Grimm 2012). After the communications blitz ends and initial volunteer excitement fades, the focus shifts to retaining volunteers. In some cases the history of the project seems to compel ongoing participation: Dunn and Westin (2008) found that volunteer numbers were related to the start date of a project – with longer running projects having greater volunteer numbers. For those researchers interested in starting up a citizen science project this is heartening; but how to retain volunteers in the short term? While many volunteers participate out of pure interest or pleasure, others are motivated by recognition and reward, and increasingly citizen science projects are turning to Web 2.0 practices such as listing top contributors, creating discussion boards, and allowing users to pick the best contributions, to motivate and retain people (Greenwood 2007, Sullivan *et al*. 2009, Goffredo *et al.* 2010, Koss 2010). Some projects, such as eBird (http://www.ebird.org accessed 19 April 2013), provide useful tools for participants, while others provide tangible gifts, like the maps of observations Wild Whales (http://www.wildwhales.org accessed 19 April 2013) sends top contributors. Sullivan *et al*. (2009) argues that in order to recruit and retain volunteers, projects must be designed with the volunteer's interest in mind. As he puts it, the researcher should not ask "what can birders do for science" but "how can we build a useful resource for birders while also engaging them in science?" (Sullivan *et al.* 2009: 2285).

Newman *et al*. (2010a) provide a useful case study of user-centered design in the iterative development of CitSci.org. The team built a website in 2005 to support an invasive species citizen science project, and then conducted a usability evaluation and used user feedback to revise the site over the next three years. In the Lessons Learned section of this paper, the authors consider development and use of geographic data (especially technology and schema selection and development), formal site evaluation (including measuring user completion rates and times for 14 tasks in four scenarios), and user feedback. Their findings are then summarized in a list of 22 guidelines. In general, they recommend designing sites to be as simple as possible while still ensuring data quality, building tools and interfaces that allow users to manipulate and report data easily, and providing tools for participant discussion with developers and with other participants. The participants wanted to have fun, be spared advertising, and to feel like real scientists. They were also interested in receiving publications which make use of the data they collect.

As most of the examples in the summary articles discussed above (Silvertown, Haklay, Devictor *et al.*, and Newman *et al.*) are drawn from US and European sources, it remains unclear if citizen science only thrives in some cultures. Dunn and Westin (2008) found examples of bird atlases (most with some volunteer involvement) covering nearly a third of the globe; however 82% were found in Europe and North America. Clearly people must be willing and able to participate, and there may be many barriers to this, including lack of access to the required technology (the digital divide), lack of time or resources, and lack of personal freedom. Given societies and cultures where these barriers do not prevent participation, allowing local control of the communication strategy is one method used to extend and internationalize user-centred design (Sullivan *et al.* 2009).

The focus on data collection in most citizen science programmes, especially in the biological conservation field, does make one question whether "citizen sensor" might be a better term for these activities (Goodchild 2007). Modern ICTs have enabled many real time sensors, ranging from satellites to weather stations to hydrological gauges. Most citizen science projects require an ability to make observations about natural phenomena that cannot be made by a machine: people must be the sensor. For instance, people can recognize many different species, but no machine has yet been built that can automate species classification in the field. Citizen scientists are trained to follow a protocol to collect, sort, or classify data. The given protocol used in most cases was developed by professional scientists, and usually the assembled data will be processed, synthesized, documented and published by professional scientists. Is the citizen really acting as a scientist if he or she only performs the part of the scientific enterprise that would be done on other projects by a machine such as a water gauge? Is the citizen scientist participating in the CBC really like Charles Darwin, as Silvertown (2009) suggests? Darwin not only volunteered to sail on the Beagle, and made many observations and gathered many specimens, but also spent many years analyzing results, and many more developing and writing his theory of evolution in *Origin of the Species*, which he then defended against powerful entities, including the church. The need to recruit and retain volunteers may convince scientists to keep using the term citizen scientist, however. Calling a bird counter a citizen scientist may over-emphasize the complexity of the task and the contribution to science; but the term citizen sensor reduces the conceptualization of the activity to less meaningful machine-like repetition. This could be an example of where purely logical scientific reasoning about terminology must bend to the perceptions of the volunteer observer in order to build large participatory networks.

The term citizen science also better reflects the important outreach, education and political empowerment components of citizen science projects. The importance of citizen stewardship, especially on private or tenured lands, in conservation biology means that it is necessary to engage the public in conservation goals. Informed and motivated citizens can also become powerful lobbyists for public conservation initiatives, including protected area designation by nations or states. Environmental non-governmental organizations, such as the Audubon Society, have long recognized the value of large vocal memberships in political campaigns where conservation values are pitted against resource extraction or other developments, and the CBC has helped to recruit and retain bird conservation campaigners as well as bird sensors. As conservation biology has always been an activist science, developed to address the global biodiversity crisis, this kind of conservation activism is itself part of the scientific process.

2.4.4. Data Collection Protocol

The data collection protocols in citizen science must consider the data needed and also the capacity of volunteers to understand and follow data capture instructions and methods. The Shorekeepers protocol and manual, for instance, was designed with a grade 10 audience in mind (see http://www.keepersweb.org/Shorekeepers/Training/index.htm accessed 19 April 2013). In some cases, face to face training sessions are provided: the Shorekeepers require that at least one member of each survey team of three or four people complete a three day training course, similar to the requirements for participating in the BC Breeding Birds Atlas. The Washington State University (WSU) Beach Watchers program takes this even further: volunteers must commit to 100 hours of training over 20 days (http://beachwatchers.wsu.edu/island/about/training/ accessed 19 April 2013). Other projects simply provide online resources, such as protocols, identification guides, and data forms, to prepare volunteers; however studies have shown that face to face training in the field often improves data quality (Newman *et al*. 2010b). The data capture itself may occur directly in the field, using data loggers or wireless devices, or data recorded in the field can be transcribed and entered into web forms. The forms may be printed out and sent via post, web-enabled to directly send data to a relational database, or embedded in a more volunteer-focused software application, such as the tools for building customized sightings lists for birders developed by Sullivan *et al.* in eBird (2009).

Some citizen science projects use photo records instead of text-based observations. For example, the E-Flora BC and E-Fauna BC projects, which provide web access to species descriptions and interactive maps displaying authoritative records from museum, academic, and professional collections, both include a citizen science component that allows registered users to upload photos along with coordinates to precisely locate them. Photographs that document observations outside of the sites' existing locations for that species are of particular interest to the scientists leading the project (Klinkenberg 2013a, b).

Citizen science protocols are discussed in some depth in chapter 3. The design of the protocol always considers the planned use of collected data; however, the CBC illustrates the fact that it is not always possible to envision in advance all the possible uses for a database resulting from a study with large temporal and spatial scales. One recent analysis of CBC data, for instance, considered the body sizes of birds in a given survey and found that they were consistently multi-modal across space and time; most surveys found a range of small, medium, and large bird sizes (Thibault *et al*. 2011). Odum (1950) predicted that CBC data could support a wide range of data mining, and this has been clearly demonstrated over the intervening sixty-plus years.

2.4.5. Data Quality

Data quality is one of the core research topics in computer science (e.g., Wang and Strong 1996, Wand and Wang 1996), and has long been considered by GIScientists as well (e.g., Goodchild and Gopal 1989, Goodchild 2008). Data quality can be looked at ontologically, as a complete encapsulation of all possible categories of data quality, such as precision, accuracy, completeness, reliability, and currency, and all the relationships between data quality categories (for instance, older data may be less accurate due to use of older locating instruments). Data quality can also be considered as "fitness for use": or how well the data can address given questions, especially questions the data was designed to address.

Wang and Strong (1996) used four main categories to organize the many dimensions and characteristics of data quality in their seminal paper "Beyond Accuracy: What Data Quality Means to Data Consumers". These categories were intrinsic, contextual, representational and accessibility data quality. This is based on 179 attributes that were identified in a survey of information professionals and MBA students. These were then organized into 20 dimensions using factor analysis, with the 15 most stable factors then placed in these four categories in a separate phase of the study.

The context of GIS differs from other information management systems. GIS originated on large, standalone computer systems developed by government or large industry, so initially the frame of reference for data quality was based largely on internal needs. The frame of reference soon grew, however, to include data standards and data assessments required for sharing data and contracting out data production. Contracting spatial data production, for instance, involves the development of specifications for products and services, including clear descriptions for how the delivered products and services will be evaluated. These specifications often refer to accepted data standards, such as those from the International Organization for Standardization (ISO): see for instance ISO 19113:2002 Geographic information – Quality principles and ISO 19114:2003 Geographic information – Quality evaluation procedures (ISO 2002, ISO 2003, Kresse and Fadaie 2004). Contractors bid on this work, and once the work is awarded and then delivered, the contractee uses the predetermined quality assessment methods to assure data quality.

Over time, spatial data began to accumulate, and before long data libraries and data warehouses appeared. To better enable search and discovery of data, indexed databases with metadata records were built. Much attention was directed to metadata, including the development of ISO standards for metadata by an international body of experts (see Goodchild (2007) for a fuller description of this). While these data and metadata did follow published standards, the standards were mainly for the producer, to describe their product, and for users in large industries, to decode data attributes. As GIS grew beyond these initial applications in government and industry, and new uses and users of GIS entered the scene, the meaning of data quality also changed. For instance, forest cover data in B.C. was developed by the government and the forest industry to capture data primarily about economic timber on Crown land in the province. As users attempted to use these data for other uses, such as wildlife habitat analysis or for assessing other non-timber forest values, the limitations of the forest cover dataset became ever more glaring, to the point that a new scheme was developed, the Vegetation Resources Inventory (VRI) (BC Ministry of Sustainable Resource Management, 2002). VRI attempts to capture many more non-timber attributes while still supporting Timber Supply Review and other traditional analyses.

As the use of GIS has expanded through society, the frame of reference became multi-dimensional. Today's data quality frame of reference includes: the academy (literature and active research); a multi- spatial data infrastructure universe, where all levels of government manage spatial data critical for business processes; mass media attention, where spatial data has gone viral through popular websites like Google Maps; and Web 2.0 phenomena such as user-generated content. Many people have the capacity to create spatial data now simply by using the GPS in their smartphones. In the face of this complexity and vast data volume, a simple general term like "fitness for use" becomes very attractive for assessing data quality!

One important use for conservation citizen science VGI is for modeling species distributions. It has long been recognized that contributed data is typically of heterogeneous spatial coverage and quality, but techniques such as cross-validation (e.g. between CBC and BBS data; Link *et al.* 2008, Butcher *et al.* 1990), filtering of low probability observations, and using large datasets, have been shown to significantly improve model fidelity. Today it is common for eBird's developer/researchers at Audubon and the CLO, for instance, to create relative species abundance models across large areas, like the continental US and Canada.

Filtering of citizen science data is done in a number of ways. First of all, most web-based projects require that users sign up before they enter data. This does represent a barrier to some potential volunteers, since many computer users prefer to be anonymous on the web. In the interest of minimizing negative impacts on volunteer recruitment, the user sign up process does not typically include many questions beyond name and email address. User Ids can be tracked to use for both recognizing and rewarding top contributors, and for screening out known vandals. Some projects employ self-screening by volunteers, such as a ratings system to rank how sure they are of a given observation (e.g. the sighting of wildlife species) as they enter the data. Software can also be designed to filter records. For instance, the CBC data upload tool automatically filters for rare birds or very high or very low species counts. Records flagged by these filters are then reviewed by a regional expert, who may decide that further review or field checks are required (Sullivan, 2009). Other filtering techniques calibrate or limit VGI data by testing of a sample of volunteered data. Silvertown *et al*. (2011) describe a process of testing volunteer capacity to detect different snail phenotypes, and then using the results to limit analysis of observations to only those records of snail types with high correct volunteer classification rates.

Following the GIS tradition of comparing a dataset with an existing standard or set of real-world locations, researchers have published several comparisons of VGI data with authoritative datasets. Haklay's (2008) comparison of OpenStreetMap VGI data to UK Ordnance Survey road data was seminal here and showed that OSM data largely met official data standards. Sabone (2009) looked at the ability of GPS-enabled cell phones to collect data with the degree of accuracy required by the Canadian Geospatial Data Infrastructure. In both cases, the specific features being captured are part of a small set – transportation routes – so data collection is very much instrumental, relying primarily on the accuracy of the GPS technology employed. Newman *et al*. (2010b) compared the ability of volunteers trained using multimedia and static online methods to correctly identify invasive species with expert plant identification. They found that while on average the volunteers did have lower correct identifications (63% for static, 67% for multimedia web training) than professionals (83%), the numbers were similar for conspicuous species. Crall *et al*. (2010) recount an iterative method for invasive plant surveys described in Stohlgren and Schnase (2006) that begins with opportunistic reports of invasive occurrences on roads across a large area. These citizen science data are then used to prioritize action and are followed up with statistically rigorous sub-sampling of nearby areas.

Goodchild (2008) suggests that in the age of VGI, metadata should be re-engineered to better provide information about how a given dataset can be used. As well as listing data standards employed, and quantifying the spatial and attribute accuracy and precision where possible, many users would be interested to discover if the data has been used previously in a study similar to their own. One interesting possibility is to use the crowd-sourcing capacity of the Web, as witnessed in Wikipedia and other sites, to generate metadata that includes reviews provided voluntarily by data users.

2.4.6. Protocol – Data Quality Relations.

The research protocol sets the data structure, as discussed above; it also affects data quality. Parsons *et al*. (2011) argue that easier citizen science is better because the volunteer may be expected to be less certain as protocols become more complex; for instance, distinguishing one species of birds from another is harder than determining that something is a bird and not a dog. As the protocol complexity increases, one may therefore expect declining data quality through either more errors in volunteered data, less contributed data, or both. This theory predicts less VGI data and more uncertainty as one moves the protocol down the taxonomic hierarchy from kingdom (e.g. Animalia) to the species level; or from groups with relatively limited diversity in a given region, such as birds, to those with much greater diversity (e.g. vascular plants).

On the other hand, the ongoing mining of the CBC illustrates that collecting data at the species level, for birds at least, has created a much richer database, with many more potential ecological signals, than a database of just "birds". Both Bhattacherjee (2005) and Silvertown

(2009) provide examples of researchers developing even more challenging protocols; the Shorekeepers protocol is also quite complex, including not only species lists but also requiring estimates of species coverage over a sample area. These protocols are based on the capacity of the average person, with a grade 10 education in the case of the Shorekeepers (see http://www.keepersweb.org/Shorekeepers/Training/index.htm accessed 12 April 2013), to observe and record a range of species or even phenotypes within a species. The citizen's capacity to sense things, especially things that are beyond the capacity of machines to sense, is a primary reason why citizen science is used in the first place. If citizens can collect more complex data, which could be expected to carry more ecological signals, why restrict them to easier protocols? Parsons suggests that it may be more useful to get many records of oiled birds after an oil spill than information about different bird species. One could counter that argument with another: it would also be useful to know how many rare birds, such as cranes, were affected by the spill, versus how many starlings. It is also not clear that demanding species-level observations is a deterrent to VGI; the CBC, with its species-level protocol, has managed for over 100 years to retain and recruit many volunteers, capitalizing on a huge public interest in birds.

The planned BC Butterfly Atlas provides for both easier and more complex data gathering with a dual protocol. People can report "Butterfly" sightings if they do not know the species, or provide observations at the species level if they are confident they have the capacity to do so. It is likely that the VGI tool that Parsons' team develops for the next version of their Newfoundland and Labrador project NLNature (www.nlnature.org accessed 19 April 2013) will allow both species observations ("coyote") and observations at more general taxonomic levels, which may include attributes ("brown dog-like creature"). This approach will allow for more data collection, albeit at a general level, as well as the species level data.

2.4.7. User-Centred Design

While "easier" citizen science may or may not be better in terms of increasing participation, there is evidence that citizen science projects designed with a user focus are indeed better in this regard. Sullivan (2009) provides an example from eBird, where significant user growth was observed after a number of tools, mostly based on providing lists of birds sighted by the user drawn from her contributed records, sorted by time or space, were provided. The Audubon Society's CBC website now includes top contributors, as does the NLNature site and others. This borrows from successful practices elsewhere on the Web, especially social media sites, where the content comes from the public and the site developers provide non-cash incentives, often recognition, but also virtual prizes, in order to stimulate participation.

Another important driver of citizen science is the requirement in many research funding programmes for public outreach or extension of research findings (Bhattacherjee 2005). Involving citizens in data collection, while providing education and communication on conservation objectives, therefore supports both science and wide-spread public awareness and implementation of the recommendations flowing from the project. As discussed earlier, Newman *et al.* (2010) include sending publications and other results of the project to volunteer participants in their list of ways to improve volunteer satisfaction and retention. The volunteer is motivated by true involvement in the scientific enterprise.

Like users of other social media applications, VGI users are now both consumers and producers of information. Goodchild (2008) pointed out that current metadata and data quality standards are challenged by these changes. New definitions of data quality from the user's perspective are now being considered: one formulation places the user's perception at the centre and states that data quality is a measure of how well data captured in a database represents the reality as perceived by the user. Yet at the same time, in citizen science projects at least, the data still must exhibit a fitness for use in addressing the research questions it was designed to address.

2.4.8. Conservation Citizen Science and Government

In many ways, citizen science is similar to the practice of contracting out data production. As discussed previously, in the early days of GIS, most spatial data was produced in-house by large government agencies, as government cartographic departments once produced all national and provincial topographic maps in Canada. Over time, government agencies evolved away from this practice and adopted policies of contracting out most data development projects to experts in the private sector. In some cases, such as OpenStreetMap, volunteer data may achieve data accuracy similar to professionally-produced data (Haklay 2008); in these cases citizen science may replace the need for both government contract administrators and the consulting sector. These kinds of cost savings are attractive to today's cash-strapped governments and promoters of low-taxation ideologies. In Europe, where biodiversity monitoring is required, the PECBM project has demonstrated that citizen science is both policy- and cost-effective and, due to the large sampling effort, may actually score higher in some data quality assessments than data produced by professional scientists.

Government-led conservation VGI projects in Canada have not been as successful to date, however, largely because there are still costs involved in developing and maintaining citizen science projects, and, especially in times of scarce resources or reduced priority of conservation within government, project budgets may be cut. The Environmental Monitoring & Assessment Network (EMAN) Coordination Office at Environment Canada was launched in 1994, and produced a series of protocols for terrestrial and aquatic biodiversity monitoring; however, funding was terminated in 2008 (Doyle 2011). The popular Shorekeepers program was put on hold in 2011 due to cut-backs in the federal Department of Fisheries and Oceans (Rasmussen 2011).

Projects which are run by non-government or academic agencies may better transcend or span the peaks and valleys of political fashion; however these projects face persistent problems as well. For instance, obtaining observations everywhere that is required in a given protocol is not always possible with volunteers. The BC Breeding Bird Atlas has relied on contracted professionals to fill several gaps in its intensive survey across the province (BCBBA Summer 2011). Professionals also provide information for upcountry grid cells in the UK Breeding Bird Survey.

This brings to a close my summary of the citizen science literature. The current rapid expansion of the practice, and the rapid pace of technological innovation as well as the social, cultural, and political changes that are driving this expansion, suggest that this won't be the final word on citizen science, however. It is a moving target: each day seems to bring more on the topic, including a brief story in this month (April 2013)'s edition of National Geographic (National Geographic 2013). As the topic spans both the mass media and the scientific literature, and is currently trending, one feels a bit like Sisyphus, endlessly pushing a rock up a hill only to have it roll down with each new round of publications. Nevertheless, I feel that at this point I have established sufficient groundwork to lay out a set of current best practices for citizen science in conservation biology. This will be the task for chapter 3.

Chapter 3. Best Practices for Citizen Science in Conservation Biology

In this chapter I will distil what I have learnt from my review of citizen science literature into five key components. The goal here is to provide guidelines and best practices for individuals and organizations that plan to conduct, or are already conducting, citizen science projects. The point of view, then, is from the project manager's perspective. I will also use these guidelines in my review of BC citizen science projects in chapter 4.

3.1. Project Direction and Management

At the outset, the project manager or project management team must undertake a set of planning activities in order to set the enterprise off in the right direction. Overall project goals and objectives must be set after considering these important factors:

i) <u>Purpose</u>: Is there a specific hypothesis, or is the project directed to biodiversity monitoring of species, ecosystem, or environmental variables? Is there a specific conservation goal, such as changes to laws or policies? Or is the purpose of the project primarily educational.

ii) <u>Governance and participation model</u>: Will the project be run from the top-down by experts (consultative/functional), through joint volunteer-expert steering committees or boards (collaborative), or are the volunteers leading the project and the experts merely serving as advisors (transformative)? Conrad and Hilchey (2011) suggest that the latter two approaches may have more impact on conservation policy, but the examples of policy impacts from the Pan European Common Bird Monitoring (Schmeller *et al.* 2009) and bird atlas projects (Dunn and Weston 2008) suggest that the consultative model can be effective as well.

iii) <u>Timeframe</u>: The project must have the capacity and resources to span the entire planned timeframe. In this regard, projects supported only by governments have shown that they may fail in times of changing government values. The not-for-profit sector, in particular ornithological societies (e.g. Audubon and Bird Studies Canada), and, to a lesser degree, academia (CLO) have demonstrated the ability to maintain long-running projects.

iv) <u>Scope</u>, including spatial extent and characteristics of the study area and target species; ecosystems, or environmental variables; and the cultural geography of the volunteer pool.

v) Resources required, including number of volunteers, number of paid staff, and equipment, supplies, and so on. Depending on the project goals, volunteer effort may need to be augmented by professional services, especially in hard to get to areas or with difficult to identify species (e.g. BC Breeding Bird Atlas).

vi) Information management: how to collect and maintain data of required quality. As there are many choices to be made with regard to hardware and software architecture, each of which can impact the ability to capture, store, retrieve, analyse, and distribute information, this topic can become very complex and typically requires the involvement of information technology experts. Projects can include information systems for collecting data in the field, systems for transmitting records, systems for storing records, systems for querying, visualizing, and analysing data, and systems for reporting and redistributing data. Consider the case of eBird, for example. The researchers have developed a website that provides an interface for contributing data, tools for visualizing data on the website, and mechanisms for using the data in other applications (application programming interfaces, or APIs). The interface for contributing data includes three steps, location ("Where did you bird?"), date and effort, and species observed ("What did you see or hear?). The location step includes a Google maps application that allows selection of an existing birding "hotspot" or creation of a new location (users can also choose to enter longitude / latitude, select an entire city county or state or import data from). The date and effort page includes radio buttons for four protocols ("Observation type": traveling, stationary, incidental or other, which has a drop down menu with random and specific options), and control boxes for entering date, start time, duration, distance, and party size. The checklists on the species page are customized for the chosen location (www.ebird.org/ebird/submit, accessed 20 March 2013). Submitted data is automatically filtered for location and individuals observed, with records outside the expected spatial or group size flagged for expert review (approximately 5% are flagged – Sullivan *et al.* 2009). The rest of the data flows into the database. A variety of tools for data visualization and exploration are provided, including range and point maps, bar charts, line graphs, arrivals and departure time lists, and a real-time submission map. There are also tools for track ones' own records. eBird data can also be downloaded to analyse in other environments (http://ebird.org/ebird/eBirdReports?cmd=Start, accessed 20 March 2013). Two different datasets are provided: the eBird Basic Dataset, a quarterly snapshot of the database that contains basic variables for species records, and the eBird Reference Dataset, which is updated annually and only includes effort-based checklists. The Reference Dataset includes environmental and spatial covariates as well as bird data, in order to facilitate modeling. All data are securely stored and backed-up daily (http://www.avianknowledge.net/content/download, accessed 20 March 2013). Data collected by eBird are pooled with other data by the Avian Knowledge Network (AKN: www.avianknowledgenetwork accessed 20 March 2013). Kelling *et al.* (2009) describe the data warehouse used by the AKN for analysis and decision-support: this warehouse consists of an event table, with information about bird observations, and multiple predictor tables that describe variables which affect bird observations. Clearly designing and implementing the information management systems that support the submission, visualization and exploration, download and offline analysis, and storage and archiving functions provided by the eBird and AVN projects requires significant resources and expertise.

The emergence of integrated web and mobile applications has the potential to reduce the complexity, required expertise and related costs, however (Newman *et al.* 2011). iNaturalist is an example of a free integrated suite of data collection, storage, and management tools designed to facilitate citizen science projects lead by non-professionals (in this case, naturalists). On the internet, iNaturalist.org provides registered users with tools to submit an observation or create projects. The Add an Observation page provides a control box for the user to enter what was seen (or pick from a lookup list), when the observation occurred, a description of the observation (freeform description, tags, and optionally additional user-defined fields) and where it was made (using a Google map interface or by entering longitude/latitude). On the same page, users can upload a photo or link to a photo hosted on social media platforms Flickr, Picasa, or Facebook (http://www.inaturalist.org/observations/new, accessed 20 March 2013). The New Project page enables users to create a project that will have its own page on inaturalist.org. Users can choose the type of project (including contest and observation contest types where contributors are ranked by number of unique species or number of unique observations submitted respectively), rules for observations, like limiting observations to certain place, and user-defined observation fields (http://www.inaturalist.org/projects/new, accessed 20 March 2013). Participants can then select projects to contribute data to: once they have joined a project, observations can be submitted online using the observation page described above. Each project page as a map for viewing observations, tools for downloading data, a journal, a list of contributors, and basic user contribution statistics (number of new users, new observations, and unique observer summed for each month observations were made and in total). See the Kootenay Camas Project at http://www.inaturalist.org/projects/kootenay-camas-project (accessed 20 March 2013), for instance. iNaturalist has also developed apps for smartphones using Apple (i0S) and Android operating systems that can be used to add observations to iNaturalist or to projects that a user has joined via the website. In this way iNaturalist provides an integrated suite of tools for project creation and management, for field data collection as well as office data entry, and for data management and storage. Offline storage is recommended since iNaturalist makes no guarantees to remain online nor will it accept liability for lost or corrupt data (http://inaturalist.org/terms.html, accessed 20 March 2013).

Another consideration is data that can be used for project evaluation. For instance, collecting information about who requests and uses project data is important to gain more insight into the value of the project and other forms of project evaluation and fundraising (Dunn and Weston 2008).

vii) Communications: what information to share, and how and when to share it. A communication plan that identifies audiences, communication types, and timing is recommended. Communications are central to strategies to recruit and retain volunteers (Dickenson *et al.* 2012). Once data has been collected and analysed, the results can be prepared in a range of formats for audiences that include scientists, managers and decision-makers, and the general public. Communications will be further discussed in the communications section below.

viii) Evaluation: what measurable outcomes will the project produce, and what specific metrics will be used to measure project success? In particular, how do the results of the project measure up to the purpose of the project as defined at i), above? Evaluation can occur periodically during a project, allowing for adaptive management in an iterative approach, or only once at the end of a project (Dickenson *et al.* 2012).

Newman *et al.* (2011: 220) prepared a framework for multi-scale citizen science project support that summarizes many of these project planning and management decisions. This method is based on a consideration of the tension or continuum of options for each aspect of the project and is useful for determining where a given projects sits within a wide range of possible project scenarios.

As the project progresses, the project leaders must monitor activities and, based on the communications plan, report out to participants, decision-makers, the scientific community, and the public. They must also take steps to adjust the direction of the project if necessary, and ensure effective management of resources and data. Ongoing project promotion and fundraising are usually required throughout a project's duration.

3.2. Protocol Development

The protocol must flow from the goals and objectives and fit with decisions made for all the factors listed above, for not only does the protocol describe the methods used to capture data and enter it into the project database, it also needs to be designed in such a way that the volunteers can use it to collect and submit data of sufficient quality to address the research purpose. Conservation scientists such as biologists, ecologists, and geographers usually lead protocol development; including social scientists, designers, communicators and educators on the team can help to meet the twin goals of scientific rigour and volunteer understanding and acceptance (Bonney *et al.* 2009a, Dickenson *et al.* 2012). Training can be used to improve the capacity of volunteers to successfully employ the protocol; however, there are limits to what training is feasible within a project budget (Greenwood 2007, Newman *et al.* 2010b).

Typically, the process of designing an appropriate protocol requires a literature review to construct a preliminary model, followed by several iterations of development in the office and testing in the field in order to refine the protocol prior to the public launch (Darval and Dulvey 1995, Bonney *et al.* 2009a, Newman *et al.* 2010b). Where possible, using an existing or standardized protocol has the advantage of easing technical barriers to pooling the data with data from other projects using the same approach. Synthesizing data that was collected using varying protocols can involve non-trivial data transformation techniques and requires metadata that describes the provenance of the data (including information on source, ownership, structure and ownership), geographic scope, and how the data were gathered and stored (Kelling *et al.* 2009), and ontologies (formal logical structures that establish a set of well-defined concepts, and how they are related, within a domain such as ornithology: see Jones *et al.* 2006, Michener and Jones 2012). Pooling enables the expansion of the spatial and / or temporal timeframe of the study; increased sample sizes and thus reduced uncertainty; meta-analysis of a set of similar projects; and comparisons across cultural and physical space (Newman *et al.* 2011). Pretesting using experts is recommended to ensure that data of appropriate quality can be collected, and tests using representative samples of volunteers and experts together can be used to ensure appropriate targets for volunteer observation (Bonney *et al.* 2009a). Protocol testing involving volunteers must consider their training needs and how training will be delivered: in particular, if hands-on field training is required as well as online training, as this will greatly affect costs and logistics (Greenwood 2007, Dickenson *et al.* 2010).

Training curricula should be designed to guide both recording observations in the field, including species or ecosystem identification and geo-location (usually with GPS), and manipulating data in the office: in particular, how to submit the data online (Jamieson *et al.* 1999). In order to reduce complete or partial data quality degradation through transcription and other human errors, most authors recommend data collection methods that have the fewest steps between observation and capture within the central database (Willet *et al.* 2010). Field data loggers, including PDAs, tablets and even smartphones, offer a technological advantage here over the pencil and waterproof notepad. Data forms which restrict data entry to selection from menus wherever possible further reduce data collection errors, as do technologies and methods to directly upload data over the Internet to protected and replicated database management systems (Michener & Jones 2012).

3.3. Volunteer Recruitment, Retention, Training, and Calibration

Volunteers of sufficient number and distribution required to adequately capture data for the research purpose must be recruited, trained, and retained. Recruitment strategies that provide benefit to the volunteer, including fun, satisfaction, and increased conservation capacity and credibility, are recommended (Goffredo *et al.* 2010, Dickenson *et al.* 2012). User-centred design of the project, and especially of the communications strategy, is gaining support as a key method for increasing volunteer satisfaction (Dickenson *et al.* 2012, Newman *et al.* 2012). Most projects launch a website as a public portal to the project, and user-centred design of this interface is critical to reduce barriers to people wishing to participate (Newman *et al.* 2010a). Using existing networks of volunteers, such as naturalist or birding networks, has been shown to be an effective way to rapidly recruit participants (Dickenson *et al.* 2012). A wide range of communications media, including print, direct mail, radio, TV or advertising are all options, but can greatly increase project costs (*ibid.*, Greenwood 2007). The explosive growth of social networking websites such as Facebook on the internet suggests using these websites or incorporating the services they provide (like bulletin boards, messaging services, and rating methods) on the project's website may provide other, lower cost means of recruiting volunteers (e.g. iNaturalist.org).

In order to retain volunteers, projects again need to show benefits to them. This can include: demonstrated use of their contributions, including on interactive maps and in reports and other publications; recognition of their efforts on the website or through other communications; and virtual or physical gifts (Newman *et al.* 2010a). There is some evidence (i.e. Dunn and Weston, 2008) that projects with a long history have the most volunteers, suggesting that the stability and sustainability of projects also helps attract and retain participants. Projects which are effective at influencing conservation policy or otherwise make participants feel empowered and involved in conservation are also expected to retain more people than projects which simply collect data for the sake of collecting data (Dickenson *et al.* 2012).

Training volunteers to use the protocol to collect and submit data may be done in several ways. The simplest, and lowest cost, method is to provide basic text instructions on a website (*ibid.*). At the other extreme is a training regime of 100 hours or more where a citizen scientist begins to look more like an actual scientist (e.g. Washington State University Beachwatchers http://www.beachwatchers.wsu.edu/regional/index.php). Once volunteers are trained, it is advisable to test their ability to use the protocol to collect and submit data. Silvertown *et al.* (2011) used a quiz to test volunteers before sending them out to detect phenotypes of snails: this was used to determine which snail species, life stages, and phenotypes could be reliably detected by them (and to limit the data analysis to where data quality was adequate). Newman *et al.* (2010) used pretests involving both experts and volunteers to calibrate volunteer data collection. Plant species which could and could not be reliably identified by volunteers relative to experts were determined in this way. The authors were also able to quantify the accuracy volunteers achieved for certain tasks (like capturing GPS coordinates and setting up sampling frames).

3.4. Data Management and Analysis

Data management and analysis are among the most important tasks for the scientist involved in citizen science projects, for even the most accurate species observations are worthless to science if they are not properly documented, stored, and analysed within a specific research context. At the very least, a central database needs to be created with an appropriate schema to enable capture, storage, processing and retrieval of information as needed for the research purpose. There is a wide range of possible data storage solutions, ranging from offline spreadsheets and single-user databases, to multi-user relational databases integrated directly with web portals, to third party management options. Increasingly, there is a desire to pool data across space and time, especially to monitor population trends and the affects of climate change (Kelling *et al*. 2009, Michener and Jones 2012): data stored on spreadsheets are particularly difficult to synthesize across projects as they allow mixing of data types (such as date, numbers, and text) within a single column (Michener & Jones 2012). Single-user databases also constrain data sharing (ibid.). More complex multi-user relational databases (also referred to as data warehouses) require significant resources to deploy (see the description of eBird in 3.2.vi above, Sullivan *et al.* 2009 and Kelling *et al.* 2009). Third-party solutions including iNaturalist (see 3.2.vi, above) offer reduced costs and ease of use; but storing data on another party's server raises questions about data security, since such data may be subject to the US Patriot Act, and data continuity, as these parties have no obligation to maintain their free services or to prevent data loss or corruption. Steps need to be taken to ensure the data stored on any database system meet the required data quality: these include data access control (such as measures to limit or filter data contributions and data downloads), regular backups, and database software maintenance. If a project opts for a third-party solution, files need to be stored offline just in case the web application development takes an unexpected turn.

Development of the database architecture (the overall design of data capture, transmission, and storage within a database system) and the data schema (formal description of the data fields and types, the arrangement of fields in tables, and the relationships between tables) should accompany the development of the research protocol. Sullivan *et al* (2009) and Kelling *et al.* (2009) describe the data architecture of the eBird project. A user-centred design process guided the development of the user interface (Sullivan *et al.*) while the data warehouse development was guided by the data analysis needs (Kelling *et al.*). In regards to schema development, Newman *et al.* provide an example of the attributes captured in a citizen science database (2011: 221). The kind of information to be collected and the kinds of data analysis one intends to conduct has a direct bearing on the data type (e.g. floating, character, date) definition for that attribute field. For instance, numeric fields cannot store letters (strings) and string fields cannot be sorted as dates.

As discussed in section *3.2 Protocol Development*, above, building data forms as a user interface to database entry is a best practice: wherever possible, using menus for users to select choices from is a proven way to reduce human errors such as typos. Placing these forms on a website or mobile device reduces the number of transcription steps and therefore the number of potential errors (Jones *et al.* 2006, Sullivan *et al.* 2009, Kelling *et al.* 2009). Here again third-party solutions such as iNaturalist simplify the process. A project management team can select iNaturalist as a data architecture solution for it provides tools for collecting (the app or the website), transmitting (the app), and storing data (the website), and use the website's tools to define the schema (by creating appropriate fields for data entry).

Tools for visualizing, reporting and analysing data are critical for project monitoring and eventual publication of results. Again a wide variety of options exist for project managers to chose from, and again these range from offline tools residing on a single computer (such as statistical packages such as SAS (www.sas.com accessed 19 April 2013). or R (www.r-project.org accessed 19 April 2013) to networked tools built into a project website (e.g. eBird's visualization tools). Higher level analysis, such as statistical modeling, are usually done offline by statisticians using snapshots or time-stamped views of the data. Projects that need or want to build and retain large volunteer numbers should provide regular updates to contributors – this suggests that online analysis and reporting tools are needed (e.g. eBird).

Database and analysis software range widely in price and the labour required for set up and maintenance. A recent search of prices using the website software.pricegrabber.com found prices ranging from $106.98 for Microsoft Access 2010, a proprietary (also known as commercial) desktop single-user database, to $22,459 for Microsoft SQL Server 2008 R2 Enterprise, a proprietary server-based multi-user relational database which can be web-enabled (software.pricegrabber.com accessed 19 April 2013). Important factors in cost determination include: offline versus online, single-user versus multi-user, open source versus commercial, few versus many records, long-time project time spans versus short-term projects, and slow response versus fast response. Offline processing by a single-user is fine for small projects, while larger projects will usually opt for online, multi-user relational databases which can respond quickly even with high numbers of users logged in and large numbers of records. Open source software is usually free to purchase but typically requires more technical skill and time to set up and maintain than proprietary software. The literature suggests that there is little difference between open source and proprietary software in terms of security (Sridhar *et al.* 2005) or reliability (Boulanger 2005).

Spatial representation and analysis of data adds another level of complexity. Web-based geographic visualization choices range from producing static maps (e.g. as image or PDF files) for simple viewing and downloading, to interactive dynamic maps that allow zooming and panning and identification of a limited set of features, to web services that allow users to interact with many data layers and perform online geoprocessing (i.e. analysis using geospatial data). The BTO website (www.bto.org accessed 19 April 2013) provides animations of the last 10 days of contributed records for many bird species: this allows users to view virtual migration as it moves across the UK. Although online geoprocessing (for instance conducting overlay analysis) is possible with the latest commercial software (e.g. Esri's ArcGIS Server 10.1, 2013), I couldn't find any examples of such tools in citizen science sites. Instead, analyses occurs offline, and then the products and results are provided online. Greenwood (2009) provides some examples of early spatial analysis, including the conversion of spot (point) values to isolines for easier interpretation. Today a common use of spatial analysis in conservation citizen science is the interpolation of point data (observations or samples) to continuous surfaces, such as the species range maps found on eBird. Spatial models can also be used to filter or red-flag submitted observations which occur in areas where a given species is unlikely to occur (Kelling *et al.* 2009).

Project data, a central asset of any project, should be widely shared in the interest of reducing barriers to information dissemination and the advance of science (Sullivan *et al.* 2009, Dickenson *et al.* 2012). Often projects allow data visualization, for instance as point locations on a map, to anybody visiting a site, but data downloads tend to be controlled to those with a login. The Audubon Society has separate procedures for people accessing a few records and for people accessing many records: the former can be accessed via an automated form, but requests for records spanning more than 10 years must be approved by a data committee. In both cases, Audubon collects information about who is requesting the information and how it will be used. Collecting this information from requestees is recommended since it helps to identify audiences and to document how citizen science data is used, which in turn can benefit fundraising and project evaluation and promotion.

As well as managing data contributions, some thought needs to be given to managing communications data. This topic is considered in more depth in the next section.

3.5. Communications

Communications are essential to all stages of any research project, from finding support for initial ideas, to building research and volunteer teams, to progress reports and updates as the project develops, to dissemination of final results. Developing a communications strategy is one of the key tasks for the project management team. This process should begin with identifying the overall audience and the component stakeholder groups within it that may require different communications plans: these groups include research collaborators, funders, volunteer participants, the media, the wider scientific community, and some portion (or portions) of the general public. The specific communications plan for each stakeholder group should consider the kind of information to share, how and when to share it, and the cardinality of the communication: i.e., is it one-way (from the research project outwards or from the stakeholder group to the research project), two-way (from the research project to a stakeholder group, and from the group back to the research group) or networked (where any individual involved in the project could potentially communicate with any other individual). It is also recommended to identify project stages or phases which may require differing communications: for instance, a media blitz to launch a project or to announce important results (Greenwood 2007, Dickenson *et al.* 2012). In large projects, an individual or agency may be identified as the single point of communication with others (the spokesperson or communications officer).

The arrival of the internet as a major tool for mass media has been a game changer for citizen science communications (Devictor *et al.* 2010, Newman *et al.* 2012). Most projects now launch a website to use as the central focus of the communications plan. This website may incorporate different content for different audiences. It may also control access to parts of the website or project data and information through login and authentication. It is common for projects to require participants to sign up through a website – this provides the option of filtering data by observer, recognizing top or novel contributors, and studying the geography, interests, and behaviour of users to further refine and target communications (e.g. eBird, iNaturalist).

Social media and other manifestations of Web 2.0 are characterized by content contributions from users; this marks an evolution or maturity of public involvement in the internet from traditional media consumers (i.e. newspaper readers or television watchers) to consumers who are also producers (i.e. bloggers who are also readers; Facebookers who post updates and read news feeds from their friends). Many citizen science projects are attempting to leverage this behaviour to increase volunteer contributions. Bulletin boards or newsfeeds are incorporated to allow volunteers to share information with, and ask questions of, each other. Some projects enable volunteer ranking of contributions through online voting or "liking" (e.g. NLNature www.nlnature.com). Top ten lists of contributors are common as a way of recognizing exceptional volunteer efforts, and hopefully harnessing social competition in a friendly and fun way (Sullivan *et al.* 2009).

A website alone is seldom adequate for all communications needs, however. First of all, as discussed above in section 3.3, above, for recruitment purposes people need to know the project and its website exist: stories in traditional media such as newspaper, radio, and TV are very useful in spreading the word. Many projects direct their communications to existing networks of potential volunteers, such as the naturalist societies or taxa interest groups (e.g. birders). Public presentations are a time tested way of reaching an audience – these often get picked up and reported in various media as well. If the intention of the project is influencing policy or law, then linkages with decision-makers and lobbying groups is required. Publications and presentations are required to assert the scientific relevance of the findings of any research: specific publications and venues that are most likely to accept the submissions and reach the target audience should be identified.

3.6. Best Practices

In order to formalize the model, the five categories of best practices (project management, protocol, volunteer engagement, data management and analysis, and communications) discussed above were organized into a table (see table 3, below). In this table, each category was disaggregated into sub-categories or elements as above. A five step likert scale (1=poor, 2=fair, 3=good, 4=very good, 5=excellent) was then used to define a range of values for each project element. As each category may be more than a simple sum of its parts, I prepared a second table (table 4, below) that considers the range of values for each category as a whole. In both tables, best practices are those in the 4 to 5 (very good to excellent) range. A rating of 3 (good) indicates a practice that is adequate to achieve typical goals in any given category or sub-category. Fair (2) ratings are those that have some clear deficiency in some important dimension. Poor (1) ratings mean that the project will most likely not be successful for one reason or another. This qualitative numerical rating system provides a way to identify where projects can be improved by adopting best practices: it also enables me to compare scores among projects and amongst groups of projects (for instance, between government-run projects and project managed by partnerships between NGOs and academic institutions).

Table 3. Best practices: sub-categories.

	1-Poor	2-Fair	3-Good	4-Very Good	Excellent
Project Management					
Clarity of mission purpose	Vague		Clear		Effective
Governance	Single agency				Multi-stakeholder
Timeframe	Indefinite		Snap-shot		Long-term, change
Scope	Undefined		Well-defined		Wide
Sufficient resources	Inadequate				Abundant
Protocol					
Appropriate for volunteers	Frustrating		Workable		Stimulating
Data entry	Freeform, offline				Structured, online
Collected data is fit for use	Unreliable		Reliable		Low uncertainty
Data can be shared and pooled	Unique, restricted				Standardized, unrestricted
Volunteers					
Recruitment	Few				Many
Retention	High drop-off				High number of repeat contributions
Engagement	Shallow				Deep
Training	Required and not available		Online only		Online and in the field
Informal learning	None		Data collection methods		Biodiversity science, sustainability
Data Management and Analysis					
Central database	Spreadsheets		Database		Data warehouse
Data entry forms	Paper				User-centered: Web or mobile
Data visualization	None		Tables		Interactive maps and charts
Data analysis	Spreadsheets		Desktop statistics		Online statistics
Data sharing	None		Internal, private		External, public
Communications					
Appropriate for audience	Message lost				Appropriate medium and message
Informative	Incorrect, incomplete		Basic facts		Information-rich
Engaging	Repels				Connects
Interactive	Static				Explorable
Dynamic	Fixed				Ever changing
Schedule	Late, few, far between				Timely, regular, often

.

Table 4. Best practices: category summaries.

	1-Poor	2-Fair	3-Good	4-Very Good	5-Excellent
Project Management	Project collapses	Project shows little activity	Project is meeting its goals and objectives	Project is having an impact on science or management	Project is having major on-the-ground impact
Protocol	Protocol is abandoned	Protocol, in some part, clearly insufficient	Protocol is working: volunteers are using it to collect data that meets quality requirements	Steps have been taken to ensure data can be shared and synthesized with other like data	Protocol includes collection of ancillary data to reduce uncertainty (e.g. effort collected to reduce observer bias)
Volunteers	No participation	Not enough participation, little training or learning: volunteers are negative	Enough competent volunteers to collect minimum required data: volunteers are positive and engaged	Enough volunteers to collect data in sufficient quantity to reduce error: Volunteers are positive and learning project's science	Sufficient volunteers to support multi-year and / or international (temporal and / or spatial) extent: Volunteers are very positive, and have a good understand of the project's scientific process and results
Data Management and Analysis	Data is lost or corrupted	Data is maintained but not used	Data is well-maintained and used by project staff (private)	Data is automatically filtered for anomalous records, some public representation (e.g. web maps) and / or some analysis results that can be used for meeting goals and objectives	Many analysis results produced. Web-based interactive tools including maps and charts for online public data exploration. Data is downloadable Data can be entered using a mobile device
Communications	Few in the past year	Some communications effort	The project has current comms	Current comms. in several mediums	User-centered, interactive and dynamic comms.

This development of a best practices model for citizen science has relied heavily on the published work of American ecologists, especially ornithologists associated with the CLO. The next chapter considers citizen science projects that are currently underway in British Columbia (BC), in order to evaluate, first of all, whether these best practices synthesized from a set of projects can be applied to a single project in a different geographic location, and, if so, how the adherence to these best practices compares to the relative success of project. If it can be shown that applying these best practices may increase project success, then I will recommend where BC projects can be improved by adopting these practices.

Chapter 4. Conservation Biology Citizen Science in BC

I will turn now to an assessment of current conservation biology citizen science projects active within BC, using the best practice model described in chapter 3 as an ideal reference case. The objective here is to determine, first of all, whether or not this best practice model can be usefully applied in the real world of current projects. If so, two more questions follow: 1) are the projects that apply these practices relatively more successful in terms of their contribution to conservation biology, and 2) are there instances where applying these best practices could improve citizen science conservation efforts. The list of BC projects that employ citizen scientists for conservation purposes that I evaluate here is not meant to be completely comprehensive, since some projects come and go while others are localized in nature. Instead, I selected projects that are at least provincial in geographic scope and are planned to exist for at least five years. Each project review includes an introduction, and then a section that considers each of the five components (project management, protocol, volunteers, data management and analysis, and communications) relative to the best practice model. In most cases, most of the information reviewed here comes from project websites. As websites have a tendency to change over time, the main project website URLs and important pages within the website domains are listed along with the date I accessed them. The full URL is only provided for the domain: subpages are denoted with "../" so that, for instance, the CBC page "../christmas-bird-count" on the birds.audubon.org domain refers to "http://birds.audubon.org/christmas-bird-count".

I begin the review with four projects collecting bird observation data, including three that are international in scope (CBC, BBS, and eBird) and a fourth that is a provincial replicant of an international effort (the BC Breeding Bird Atlas). As noted in the previous section, the best practice model was largely built upon the characteristics of these very successful projects, especially the long-running CBC and BBS. Clearly these projects are likely to score well against a model that was developed using them as key examples. Including them here allows me to consider how well these international projects are working out in the BC context. It also allows me to provide more details about these projects and to see how other projects compare. The four bird projects are organized chronologically, with the oldest project, the CBC first, followed by the BBS, the BC Breeding Bird Atlas, and eBird. This ordering illustrates how the practice of citizen science has evolved in ornithology in response to changes in technology and project design theory.

At the end of each project review I provide a qualitative rating using a likert scale (1 = poor, 2= fair, 3=good, 4=very good, 5 = excellent) for each of the five components of the best practices model: project management, protocol, volunteer recruitment and retention, data management, and communications. These ratings are then used to compare the projects with each other in section 4.13 at the end of the chapter.

4.1. Christmas Bird Count

URL: http://birds.audubon.org/ and ../christmas-bird-count accessed 5 Jan 2012

The CBC is a continent-wide effort to measure early winter bird populations. This project has been running since 1900 and is considered to be the world's longest running citizen science project. Twenty-five locations were surveyed by twenty-seven observers during the first count in 1990 – this included a survey in Toronto, Ontario. By 2010 there were 2215 circles (see section 4.1.2 below for a definition of the survey protocol) surveyed by 62,624 observers (52,850 field observers and 9774 feeder watchers) according to the report for the 110th CBC (LeBaron 2011). See ../history-christmas-bird-count for more information on the history of the CBC. Although the US National Audubon Society manages the overall CBC enterprise, the CBC in Canada is managed by Bird Studies Canada, and for many years there have been large numbers of Canadians participating. In the 109th CBC for instance, there were 394 circles with counts in Canada between the 14th of December 2010 and the 5th of January, 2011 (Canning 2011). Canning provides a full review of the Canadian 2011 counts in American Birds (Volume 65) published by the Audubon Society.

4.1.1. Project Management

The CBC is led by the National Audubon Association in the U.S. (www.audubon.org accessed 5 Jan 2012) and by Bird Studies Canada in Canada (http://www.bsc-eoc.org accessed 5 Jan 2012). The CBC employs regional coordinators and each survey circle has a leader and a data compiler who is responsible for submitting collected data. Regional editors oversee the project at the provincial, state and other regional level (see ../programs/cbc/cbc-regional-editors (accessed 5 Jan 2012) for a complete list). The National CBC Coordinator for Canada is Richard (Dick) Cannings (see ../volunteer/cbc/index.jsp?lang=EN&targetpg=index accessed 5 Jan 2012).

4.1.2. Protocol

Butcher (1990, pg 130) provides a summary of the CBC's methods:

"The CBC consists of 1-day counts, within 25-km diameter circles, by 1 to 230 field observers and 0 to 343 feeder watchers per circle per year within 12 days of Christmas Day. Most counts divide observers into parties of 1 or more people. Each party keeps a record of the number of hours in the field and the number of miles covered. For analysis, the number of birds of each species counted within each circle is usually standardized by dividing by the number of party hours (Bock & Root 1981)".

4.1.3. Volunteers

Volunteers are recruited through the birding and conservation communities and through the project's websites at Audubon and Bird Studies Canada. Bock and Root (1981) make some interesting comments on strategies for volunteer retention, including supporting an earlier author's caution (Hickey 1955) about not changing the event too much, lest volunteers stop having fun and quit. The CBC Review Panel (Francis *et al.* 2004) agreed with this sentiment during its review and chose to make subtle rather than wholesale changes to the protocol. Although no training is required to participate in the CBC, leaders for each circle must ensure that his or her team is capable of observing birds and also identify a data compiler who is responsible for data entry. Volunteer resources are provided online at ../compilers-participants and http://www.bsc-eoc.org/volunteer/cbc/index.jsp?lang=EN&targetpg=index (accessed 5 Jan 2012 – see Links for Compilers). Bird Studies Canada is currently in the process of adding an Our CBC Volunteers page at http://www.bsc-eoc.org/volunteer/cbc/index.jsp?targetpg=cbcvolunteers&lang=EN (accessed 5 Jan 2012) which presumably is part of the projects volunteer recruitment and retention strategy. The President & CEO of Audubon, David Yarnold, wrote a letter to volunteers thanking them for their participation in the 111th survey (see ../sites/default/files/documents/yarnold_cbc_letter_2011.pdf). This letter lists the general uses of the data in science, policy, and management, and concludes that the volunteer efforts in the CBC are "at the core of Audubon's role as America's leading advocate for birds". In the same letter Yarnold uses [was he the first to 'coin' it?] the term "crowdscience" to describe the volunteer efforts at Audubon.

4.1.4. Data Management and Analysis

Audubon's CBC website describes data management and analysis as follows: "You do the actual counting, but Audubon and our partners work hard to organize and analyze the data you provide us with." (../data-research). Both the Bird Studies Canada and Audubon sites point to a single data entry location at http://netapp.audubon.org/appportal/login.aspx?app=CBC (accessed 5 Jan 2012) or http://app.audubon.org/josso/signon/login.do (accessed 5 Jan 2012). Users must be registered and are authenticated through entry of a username and password.

Audubon's data and research page listed above provides links to annual summaries and reports. Hundreds of scientific articles are listed on the bibliography page at ../christmas-bird-count-bibliography-scientific-articles.

Although Bock & Root (1981) bemoan the lack of structure in the CBC, calling it a kind of bird watching contest rather than a scientific survey, they go on to list a series of useful insights derived from the CBC that were later confirmed by more rigorous methods such as banding birds, including the southern eruption of typically boreal birds. The authors also note that a comparison of CBC data with "authoritative" migratory bird data from the Long Point Observatory concluded that the CBC indices could be used to monitor bird populations of many species with more precision than previously suspected. Butcher *et al.* 1990 also found that the CBC did not meet a scientific standard for an ideal survey, leading to concerns about the reliability of population data derived from the CBC. Major scientific shortcomings including the lack of standardization of travel paths and survey effort within the survey circles, and the observation that participants are often more interested in recording the most species rather than conducting a count intended for comparisons of relative species abundance. Researchers found ways to improve results through techniques such as adding Breeding Bird Survey (BBS) data to their analyses (*ibid.*).

The Strategy for Improvement provided by the CBC Review Panel (Francis *et al*. 2004) specifically addressed the concerns around standardized effort (through a recommendation requiring separate reporting of birds observed using different types of effort (home feeder-watching, owling, and roost counts) and standardized sampling components within count circles (which could include standardized routes or specific areas within the circle that are thoroughly counted each year). They also made recommendations designed to increase the scientific value of the historic database, including using the best available statistical methods (e.g. non-linear modelling of the relation between number of birds counted and effort and appropriate weighting to adjust for uneven survey density within count circles) to estimate species-specific effort-adjusted annual indices and trends, and making these adjusted indices and trends widely and easily available. As a result, the CBC continues to be used in a range of analysis by non-CLO researchers, including a body size analysis in the 2011 paper by Thibault *et al*.

A final recommendation from the Review Team was to continue to develop the educational and outreach potential of the CBC to promote citizen science. In particular, the review team called on Audubon to tailor the project web site for use by a variety of audiences, including scientists, conservationists, CBC participants, birders, and educators, and to present results, interpretations, and other materials separately as appropriate for each audience component.

Once filtered and processed by the CBC team, the data is shared with the Avian Knowledge Network (AKN) where it comprises one of 60 datasets stored with associated metadata within a sophisticated data warehouse (Kelling *et al.* 2009). In order to synthesize data from all these diverse projects into a single observation event table, the AKN developed a Bird Monitoring Data Exchange (BMDE) data model: an ontology that captures as many data elements as possible to describe the bird observation event. The BMDE's schema is based on the Darwin Core, an international metadata standard, with extensions to describe bird occurrence characteristics. Each contributing organization then mapped its data to the BMDE, and then the Distributed Generic Information Retrieval (DiGIR) protocol is used to automatically transfer data from contributing organizations to the data warehouse (*ibid*.: 615). In 2008, the data warehouse contained more than 60 million bird observations gathered at more than 425,000 locations in the US. Each of these observations was linked to more than 500 predictor variables describing the birds' environment. The large volumes of high-dimensional data are then analyzed to discover complex patterns using visualizations, simulations, and model building. These patterns in turn provide insight for developing hypotheses about the underlying ecological processes that produced the observations. This process of ordering and then analyzing large volumes of data from different studies is essentially a meta-analysis but was termed "data-intensive science" by Kelling *et al.* and the information technology that underpins it has been termed "Ecoinformatics" by Michener and Jones (2012). Thus the CBC continues to affect science and innovation, even as science and innovation improves the utility of the CBC data.

As Bock & Root (1981: 17) stated, with the CBC we can at least ask questions about winter bird population abundance "on a geographic scale not possible for any other organisms". 30 years ago, they already recognized that Eugene Odum's 1950 quote that "One has the feeling that there is more gold buried in the mass of data than has yet been uncovered" was prescient (ibid, pg 23). Using the latest data management and data analysis techniques, researchers continue to sift the CBC for a richer understanding of bird ecology and bird conservation planning.

4.1.5. Communications

The Audubon society's website is the primary communications interface for the CBC. Bird Studies Canada's website at http://www.bsc-eoc.org/volunteer/cbc/index.jsp?lang=EN&targetpg=index (accessed 5 Jan 2012) is quite basic and sends the viewer to the Audubon site for more information. As discussed above, both the US and Canadian sites provide volunteer resources and a single point of data entry through the websites. Bird Studies Canada provides a press release template that can be customized, see http://www.bsc-eoc.org/download/CBCmediarelease.doc (accessed 5 Jan 2012). The thank you letter from Audubon President & CEO David Yarnold discussed in the volunteer section above is an excellent example of direct communication from the leader to the participants informing them of the value of the efforts.

The results of the annual survey are published in American Birds journal. The Audubon's website provides links to this and a bibliography of hundreds of articles at ../christmas-bird-count-bibliography-scientific-articles .

The Audubon website at ../historical-results provides some tools for public data visualization and access to the compiled data. Here, people can create a chart or access a limited number of records for a given survey circle or species (or set of these) via database queries, view the resulting table online, and download records as a comma separated values (CSV) text file. Weather and effort data as well as species data is available. On 5 Jan 2012, the temporal range of available survey data extended continuously from the first survey in 1990-91 to the 110th survey from Christmas 2009-10.

It is also possible to contact CBC staff via the websites' "contact us" link to make a custom request. For instance, I emailed a request for the latitude and longitude of the centroid of all BC survey circles for a period of 10 years on Monday, July 18th, 2011 and was contacted the next day by a representative of Audubon Science who told me that pulling raw data was possible, asked me to read their data use policy at ../documents/cbc-data-use-policies , and then complete a data agreement form at ../documents/cbc-data-request-form or provide similar info in an email. I completed the online form and sent the output XML file back on the 28th of July 2011. On 1 August 2011, the Audubon representative replied that requests for more than 10 years of data or for an entire province or state had to be approved by the CBC Director and the Bird Conservation Director, and that in some cases a Memorandum of Agreement (MOU) was required. As I requested all data for BC, a paragraph summarizing how I planned to use the data was needed to process my request. I responded the same day, and then on 4 Aug 2011, I was informed an MOU would be needed; this was attached as a PDF. On the 8th of August I faxed the signed form and on the 16th of August I was notified that my data was ready for downloading. The whole process required less than a month to complete.

Clearly Audubon has policies and processes in place for sharing data that are structured to limit liability and data use while ensuring Audubon retains data ownership. The process also provides a means for Audubon to both filter and track data requests and how CBC data is put to use. In particular, this can help Audubon track publications that make use of CBC data, a process that would otherwise be a challenge in the current world of many diverse journals and other communications. Tracking requests also provides information that can assist project evaluation, promotion, and fundraising.

4.1.6. Current Status

In 2011nearly 12,000 people participated in the 111th CBC in Canada. 394 circles were surveyed and approximately 3.3 million birds were observed (Cannings 2011). This is the largest number of circles ever surveyed in Canada, 11 more than the previous high from the 110th CBC. In BC there were 89 counts with 2434 field observers, and over 1,100,000 individual birds and 221 species were recorded. The highest species count for BC came from Ladner (144 species – *ibid.*: 8). Four new species never before detected in Canada during the CBC were found, including, in BC, a Costa's hummingbird at Vancouver and an Acorn Woodpecker in Abbotsford-Mission , raising the all-time Canada CBC list number to 424 species. Cannings' report in volume 65 of American Bird Journal provides a two page summary on the 111th survey in Canada (see ../sites/default/files/documents/ab_111_7-9_canada.pdf).

The final words:

"CBC's appear to be surprisingly good indicators of pattern in avian geographical ecology, if they are used carefully and conservatively, and especially if they are used in large numbers."

Overall qualitative rating (1 poor to 5 excellent):

Project Management

Rating: 5. Spatial and temporal scale maintained, use of data for science, management, education

Protocol

Rating: 5. Simple and, through the adoption of standardized effort and sampling methods, effective.

Volunteers

Rating: 5. 2434 field volunteers were involved in BC last year. The CBC helped to create birding culture and in return birders continue to enjoy the CBC. The longevity of the project is another important factor leading to the large volunteer numbers. Barriers to participation are low: no training is required.

Data management

Rating: 5. The large volume of data collected by the CBC was a challenge to mine before the arrival of the computer. In recent years, Audubon, CLO and AKN met this challenge through the implementation of state-of-the-art data warehousing and analyzing systems. Data is available for download.

Communications

Rating: 5. Information appropriate for a range of audiences is regularly and expertly produced. Most information is self-serve through web sites, increasing flexibility of data access and decreasing the per-user staff costs of meeting data access requests.

4.2. Breeding Bird Survey

URL: www.pwrc.usgs.gov/bbs (US) (accessed 14 Jan 2012) and www.ec.gc.ca/reom-mbs/default.asp?lang=En&n=416B57CA-1 (Canada) (accessed 14 Jan 2012)

The impetus for the Breeding Bird Survey (BBS) was a hand-written letter to the US Fish and Wildlife Service asking if the American robin was experiencing a continent-wide population decline due to DDT poisoning in the late 1950s (Ziolkowski *et al*. 2010). The letter was directed to agency biologist Chandler S. Robbins who replied that no scientifically rigorous programs existed that could answer this question. Robbins started thinking about how to fill this knowledge gap by conducting statistically appropriate surveys over large spatial extents in order to monitor bird species. In 1962 Robbins learnt about the planned British Common Bird Census, which employed a similar protocol to the National Audubon Society's Breeding Bird Census (BBC): observers selected a plot of land of fixed size and visited it at least eight times per year to record breeding territories. Robbins was a BBC observer and knew that only 20 sites had been continually sampled in the US at that time, leading him to conclude that a point sampling method would be much less time consuming and thus more likely to succeed on a continental scale than a territory sampling method. The experience Robbins himself had with the Mourning Dove Call Survey, and the work his brother Sam Robbins did with a Wisconsin Summer Bird Count, demonstrated the utility of a protocol consisting of point surveys at regular intervals along roads. The former project used professionals, which Chandler realized would be cost prohibitive at the continental scale, while the latter illustrated observer bias resulting from volunteer route selection. To address the survey spatial bias, he used paper maps and random number table to divide states into blocks of one degree longitude by one degree latitude and then selected a set number of random route start points and directions within each block. Test surveys were used to develop methods for reducing observer bias by including species identification certainty and habitat type (which influences ability to observe species) in the data forms. The first pilot surveys were undertaken in 1965 in Maryland and Delaware. In 1966, the BBS was officially launched with 600 surveys in the eastern US and Canada. By 1968 that number had grown to 1,850 routes covering the continental US and Canada (*ibid.*). Currently there are more than 4000 active routes on the continent north of Mexico (USGS 2011).

4.2.1. Project Management

The BBS is jointly coordinated by federal agencies in the US (the US Geological Survey (USGS) Patuxent Wildlife Research Center) and Canada (the Canadian Wildlife Service (CWS), National Wildlife Research Centre). In Canada, Bird Studies Canada, an NGO and co-partner of Birdlife International, partners with CWS to manage the project. Provincial coordinators organize volunteers and collate results. CWS' website lists Canadian regional coordinators at http://www.ec.gc.ca/reom-mbs/default.asp?lang=En&n=C6E31C35-1 (accessed 14 January 2012). Dick Cannings is BC's BBS Coordinator (Bird Studies Canada 2011).

4.2.2. Protocol

Surveys are done at the height of the avian breeding season (June for most of North America). Trained volunteer observers capable of rapid and accurate bird identification complete pre-determined routes that are 39.4 km (24.5 miles) long consisting of 50 stops 0.8 km (0.5 miles) apart. At each stop, volunteers spend three minutes observing and recording the total number of each bird species seen or heard within approximately 400 metres (0.25 miles). Surveys begin 30 minutes before sunrise and usually take about five hours to complete. Volunteers are requested to commit to surveying a given route for several years to reduce variability (Bird Studies Canada 2011; US Geological Survey 2001). A detailed discussion of the protocol is provided on the CWS website at http://www.ec.gc.ca/reom-mbs/default.asp?lang=En&n=C6E31C35-1 (accessed 14 January 2012) and on the USGS site at http://www.pwrc.usgs.gov/bbs/participate/training/ (accessed 14 January 2012).

4.2.3. Volunteers

Volunteers are recruited from the birding and naturalist communities and directly through the program websites at http://www.pwrc.usgs.gov/bbs/index.html (USGS, US) (accessed 14 January 2012) and http://www.ec.gc.ca/reom-mbs/default.asp?lang=En&n=2F5AC989-1 (CWS, Canada) (accessed 14 January 2012), as well as through partner sites such as Bird Studies Canada's page at http://www.bsc-eoc.org/volunteer/bbs/index.jsp?lang=EN&targetpg=index (accessed 14 January 2012). The US site provides learning resources including a description of the protocol, the Dendroica bird sight and sound reference tool, narrative descriptions of features used to identify birds, and a bird quiz to test knowledge. Printable forms for surveys, region specific field sheets, and a data entry and review portal (supported by a guidance document) are also provided on the US website. The CWS site includes detailed instructions, printable forms, and links to the Dendroica tool and Internet data entry portal hosted by USGS.

The CWS website also includes other contributions from volunteers including a poem, testimonials, and the results of a 2004 survey of current and recently retired BBS participants in

Canada (for the latter see http://www.ec.gc.ca/reom-mbs/default.asp?lang=En&n=929AA800-1 accessed 7 Jan 2012).

The participant survey results provide interesting insights into the skills and experience of these individuals and how and why they participate in the BBS. In regards to skills and experience, the average number of years birding for the 263 respondents was 28.4 with approximately 89% (235) reporting at least 10 years. Almost half (47%) were natural science professionals while 13% conducted BBS surveys as part of their jobs. As such, these participants don't all fit well with the citizen scientist definitions proposed by Silvertown (2009) and Greenwood (2007), since a significant percentage are not volunteering their time; while nearly half, as natural resource professionals, are not completely outside the academic community as required in the general definition for citizen scientist provided in Lepczyk *et al.* (2008). This set of participants was therefore relatively more scientific than the typical citizen scientist as defined by these authors; this would be expected to result in data quality more similar to that of data produced by scientists than that of data flowing from a typical citizen science project. It might also be more accurate to describe the survey as a "volunteer and in-kind professional" survey instead of as a true volunteer survey (Environment Canada 2012).

Recruitment of participants was mostly reported as either volunteered directly (n=120 or 46%), or recruited by a colleague or friend (79 or 30%) or a BBS coordinator (73 or 28%), while only 8 people (3%) responded to a media request (multiple answers were possible – percentage adds up to 107). It is unclear how the people who volunteered directly learned of the survey, or if that group includes participants that did the work as part of their jobs. Retention was measured through number of years running a route: of 236 people running at least one route, each had been running that route for an average of 10.1 years (with a frequency distribution ranging from 91 (39%) in the "1 to 5 year" class to 27 or 11% in the "greater than 20 years" class). A notation is attached to these tables reporting an unpublished mean estimate of 7-8 years for an individual running the same route that was derived statistically from BBS data. The long mean involvement in running a given route is also likely to improve data standardization. Participant motivation was led by personal enjoyment (80%) and contribution to conservation (70%).

The USGS conducted a similar survey of US BBS participants in 1997; results can be seen at http://www.pwrc.usgs.gov/BBS/bbsnews/Poll98/ (accessed 7 Jan 2012). Here we see that 666 or 46% of respondents (n = 1456) were professionals in the natural resources field, while 372 or 24.4% participated in surveys as part of their job. Again around 89% (1292) of respondents (n=1452) had over 10 years of birding experience.

4.2.4. Data Management and Analysis

Data is either submitted by participants using a single Internet data entry portal access maintained by USGS, or sent in by mail on forms and scanned in (http://www.ec.gc.ca/reom-mbs/default.asp?lang=En&n=5EE0ADBA-1 access 14 January 2012). These data are automatically filtered for factors expected to contribute to variation among the data, including weather, time and date of survey, and differences among observers. Routes that are run by the same observer within 19 days are grouped into subroutes. Surveys conducted during high winds (generally force 4 on the Beaufort scale, or force 5 in the Prairies), outside allowable dates (28 May through 7 July), or outside of allowable time (started more than an hour after prescribed time or ended after 11:00 AM local time) are not included in the analysis. For a given species, minimum thresholds for the number of observations in a given year (at least 15 routes where the species was recorded at least twice) and across all years (at least 40 individuals) are also used as filters.

The data which passes through these filters are then analyzed to produce annual indices of relative abundance. Fluctuations of these annual indices are assumed to be representative of the trends in the overall population. See http://www.mbr-pwrc.usgs.gov/bbs/genintro.html (accessed 14 January 2012) for a general introduction to BBS data analysis. Until 2009, the route-regression method used to analyse annual indices and population trends followed Geissler and Sauer (1990) (See http://137.227.242.23/bbs/trendin.html (accessed 14 January 2012) for an overview). The analysis method for Canadian data is further described by Downes and Collins (2003). The trend is defined on the CWS site as:

"… the mean annual percent change in bird population. The trend is based on the slope (b) of a regression line fitted to the natural log of annual indices. The trend is given as the annual percentage change and equals 100(exp(b)-1)." (http://www.cws-scf.ec.gc.ca/mgbc/trends/index.cfm?lang=e&go=pop.definitions accessed 14 January 2012).

Since 2009, analysis of BBS data has moved from this method of estimating equations to a method using hierarchical models as described in Link and Sauer (2002). See http://www.mbr-pwrc.usgs.gov/bbs/gra08/Comp_trnd_help_file.html (accessed 14 January

2012) for an overview. The estimating equation method and the hierarchical model methods are compared in Sauer and Link (in press).

In Canada, trend estimates are created for individual species with sufficient records meeting the above conditions, and are grouped according to geography (Canada-wide, province or territory, and bird conservation region), migratory pattern (neotropical migrants, short-distance migrants, and year-round residents), and habitat group (grassland, woodland, wetland, scrub or successional, and urban or suburban). Canadian results from the 2009 survey (using the historical estimating equations method) can be queried online at http://www.ec.gc.ca/reom-mbs/default.asp?lang=En&n=0D74F35F-1 (accessed 14 January 2012). Trends are reported for four time periods: all records (1970, 1973 or 1986 to 2009), 1970 or 1973 to 1989, 1999-2009, and 1999-2009[7]. In each time period, the trend, statistical significance (either $P < 0.05$, $0.05 < P < 0.1$, or no significance) and number of total routes used in the analysis are reported. See http://www.cws-scf.ec.gc.ca/mgbc/trends/index.cfm?lang=e&go=info.GuildTrendHabitat&GuildID=3 accessed 14 January 2012.

The USGS BBS website reports data for two time periods, 1966-2009 and 1999-2009, for Canada and the US. Trends are available for individual species and are grouped by geography (nation, state or province, bird conservation area), and habitat use and migration pattern (with the same categories as reported on the CWS site, see above); additionally they are grouped by nest type (cavity nest, open-cup nest) and location (ground or low nesting, mid-story or canopy nesting). The results of the analysis are reported differently than on the Canadian site: the table for individual species shows the trend (mean), number of routes used in the analysis, and 95% confidence interval. The grouped data includes the trend, the number of observed species in the group, and the proportions of species with statistically significant ($P < 0.05$) positive and negative trends. See http://www.mbr-pwrc.usgs.gov/bbs/trend/guild09.html accessed 14 January 2012.

The detailed protocol, high level of participant expertise, and professional data management and analysis behind these trends makes them widely accepted and used by the

[7] The differing start dates for the first two time periods are due to the staggered rollout of the BBS across the country.

professional scientific and resource management communities. According to the USGS website, the BBS data are used in the following ways:

1. The U.S. Fish and Wildlife Service, Canadian Wildlife Service, and Partners in Flight all use BBS trends along with other indicators to assess bird conservation priorities.
2. BBS data were instrumental in focusing research and management action on neotropical migrant species in the late 1980s, and on grassland species in the mid-1990s.
3. State Natural Heritage programs and Breeding Bird Atlas projects often utilize BBS data to enrich their databases.
4. Educators often use BBS data as a tool to teach biological, statistical and GIS concepts.
5. More than 270 scientific publications have relied heavily, if not entirely, on BBS data. USGS 2001.
   (http://www.pwrc.usgs.gov/bbs/about/ accessed 14 January 2012).

In Canada, the BSC's datasets are georeferenced and maintained at the organization's GIS Laboratory. A range of Internet Map Services provide access to the data in both WMS and WFS formats. The latter data can be downloaded.

4.2.5. Communications

As the BBS is lead by government agencies in Canada and the US, the websites are built on government templates and exhibit more of a top-down communication approach than does the Audubon CBC site. The data is also not as current, with annual indices only available to 2009 on both the CWS and USGS sites. The USGS provides regular memoranda to participants at http://www.pwrc.usgs.gov/BBS/bbsnews/Memos/ (accessed 14 January 2012) - the most recent is from the summer of 2011 There is an indication that some communications have been curtailed: for instance, the latest newsletter on the CWS site is Number 2006 from winter 2006 (see http://www.ec.gc.ca/reom-mbs/default.asp?lang=En&n=242C5012-1 accessed 14 January 2012), while the USGS site provides access only to summaries from the early to mid 1990s at http://www.pwrc.usgs.gov/BBS/results/summaries/index.html (accessed 14 January 2012) . Data and trend analysis results from the BBS are widely published in the scientific literature, however; a bibliography of articles published to 2009 is accessible as PDF from www.pwrc.usgs.gov/bbs/about/bbsbib.pdf (accessed 14 January 2012) or in field-searchable web format at http://www.pwrc.usgs.gov/library/bibs.cfm (accessed 14 January 2012) (although I encountered an error when trying to search for BBS data from http://www.pwrc.usgs.gov/rwp/database_descriptions.htm#PWRCbib on 14 January 2012). The BBS memo from the summer of 2011 indicates a 32% increase in publications since 2005.

4.2.6. Current Status

The BBS Memo from the summer of 2011 (http://www.pwrc.usgs.gov/BBS/bbsnews/Memos/BBSMemoSummer11.pdf accessed 14 January 2012) provides some information on participation in the 2010 survey. In Canada, 498 of 973 existing routes were surveyed in 2010; this is one more than were surveyed in 2009. 70 of 133 existing routes were surveyed in BC, up from 65 in 2009. The numbers were down in the US, with only 2468 of 3512 routes surveyed in 2010, compared to 2623 in 2009. The CWS site provides a table of BBS participation rates in Canada from 2001 to 2009 (http://www.ec.gc.ca/reom-mbs/default.asp?lang=En&n=207A6123-1 accessed 14 January 2012). The numbers don't quite match those on the USGS site: here we see a total of 466 routes surveyed in Canada, and 57 in BC, in 2009. In the 2001-09 period, the number of routes surveyed in Canadian ranged from 428 in 2003 to 510 in 2007; while the number surveyed in BC fell steadily from a high of 81 in 2004 to a low of 57 in 2009. A graph on the page illustrates that most of the increase in the numbers of routes surveyed in Canada occurred in the periods 1965 -74 (from less than 50 at the launch of the program in 1965 to around 250 in 1974) and 1989-95 (from around 200 to approximately 450).

Overall qualitative rating (1 poor to 5 excellent):

Project Management

Rating: 5. Spatial and temporal scale maintained or increasing, use of data for science, management, education.

Protocol

Rating: 5. Standardized and efficient point count, with randomized study design.

Volunteers

Rating: 4. 57 routes in BC for last year reported (2009). Surveys of Canadian (2004) and US (1997) participants revealed that nearly half of the participants in Canada and the US do the work as part of their jobs, so only just more than half are actually volunteering their time. Training is done online.

Data management

Rating: 5. The large volume of data collected by the BBS is analyzed by professional groups within the USGS and the CWS-Birdlife Canada partnership. Downloadable data is available.

Communications

Rating: 4. The project scores well on scientific and management communications, including publications, but not so well on public communications, since the web sites and newsletters are out of date. Downloadable data is available.

4.3. B.C. Breeding Bird Atlas

URL: www.birdatlas.bc.ca (accessed 19 January 2012)

The B.C. Breeding Bird Atlas (BCBBA) project is a seven-year effort to determine the distribution and relative abundance of breeding birds in BC. The results, according to the BCBBA website, "will form a foundation for conservation policy and legislation and to ask important questions about how climate change affects on our environment, species at risk, environmental assessment and how to keep common birds common"(../english/aboutatlas.jsp). Both paper and online versions of the final atlas are planned.

4.3.1. Project Management

The BC BBA is a partnership between environmental NGOs (Bird Studies Canada, the BC Field Ornithologists, Federation of BC Naturalists, the Biodiversity Centre for Wildlife Studies, and the Pacific Wildlife Foundation), government agencies (Environment Canada's CWS, and the BC Ministry of Environment) and the private sector (Louisiana Pacific Canada Ltd.). The project is governed by a steering committee with representation from the partners and supported by technical committee that also draws from these organizations. Operations are lead by Christopher Di Corrado, Atlas Coordinator (Dr Rob Butler according to ../english/atlascontact.jsp, or Christopher Di Corrado according to the BC BBA Newsletter Summer 2011), and other staff working out of Coordinating Office located at the CWS Pacific Wildlife Research Centre in Delta, BC. Regional coordinators manage activities in 41 Atlas regions across the province.

4.3.2. Protocol

The BCBBA protocol divides the province into 10 km x 10 km UTM grid cells (100 km^2 in area). Each of these cells will be visited during the summer over the 7 year duration of the Atlas project to detect evidence of breeding. Point counts at specific locations are also taken; these data are used to estimate relative abundance of species, and locate population centres. Maps of relative abundance are created from point counts using a kriging method (Davidson 2011). The protocol is described in detail in the BCBBA Guide for Atlassers (2009) which is available for download from ../download/bcatlas_guidelines.pdf. The protocol allows for three levels of participation as described on the site:

1. Tell us where you saw breeding birds. This is as simple as recording where you saw a bird at a nest, feeding its young or where you heard it singing.
2. Tell us how many birds you saw. Here you will join a team of experienced birders who follow a predetermined route to record all birds seen or heard first thing in the morning.
3. Tell us about birds that are rare or nest in colonies. We provide a list of species in your area that are of high conservation concern because they are rare or nest in colonies. You provide us with details such as how many birds you saw, where they nested, and how many young were present.

(BCBBA 2011, ../english/aboutatlas.jsp).

The online data entry form includes choices of point count, linear transect, modified transect, area search, casual observations, carcass search, radar monitoring, and electroacoustic monitoring, so it clearly provides for both VGI and professional data contributions.

Data downloaded from the BCBBA website indicates that the protocol used is NORAC (North American Ornithological Atlas Committee) 2006, available at http://www.bsc-eoc.org/norac/atlascont.htm (accessed 19 January 2012).

4.3.3. Volunteers

Volunteers are recruited from partner organizations, from the vast networks of birders, and through outreach efforts, including the project website. They do not need to be experts – the project welcomes all contributions. Regional coordinators organize volunteers and provide training and data quality assurance. The top ten volunteer contributors (by number of records, hours, squares, species, or point counts) are recognized on the BCBBA website's homepage (../english/index.jsp). Some funding is available for travel to remote locations. All volunteers can submit travel expenses to BCBBA and receive donation tax receipts and reimbursement cheques. See the 14 September 2011 news post at ../bcdata/newsarchives.jsp?lang=en.

The BCBBA website provides a range of resources for volunteers, including the protocol as a PDF manual, data forms (coding sheets) and species lists for each region, news and newsletters, a query interface for searching data summaries, and an online data entry portal (with an FAQ). Volunteers can either submit the scannable coding sheets to their regional coordinator or upload data to the online portal. Several online mapping tools have been developed to help volunteers choose cells to visit, download GPS locations for point counts, or browse existing data. PDF Maps from GeoBC are downloadable by Atlas volunteers free of charge (see ../bcdata/pdfdownload.jsp?lang=en).

Volunteer effort is recognized on the project website at ../userstats.jsp?lang=en . Here, a complete list of all volunteers that have contributed to the project (except those that chose not to allow this) are listed and ranked by the number of records entered (the data can be sorted on other columns as well).

4.3.4. Data Management and Analysis

Data is captured online through the Birds Canada website. Expert review of Atlas data is provided by the Regional Coordinator network and a Data and Records Verification Committee. Data are available for download from www.naturecounts.ca (accessed 19 January 2012); however, since these data are given and access level 3 rating, requests must be approved by the data custodian. Approximately 70 data requests have been approved and processed since 2008, and many biologists directly access processed information directly from species and effort maps and summaries from the BCBBA website. Data sharing agreements are in place with government agencies, NGOs, forestry companies, and guide-outfitting/eco-tour businesses (Davidson, 2011).

4.3.5. Communications

The BCBBA website is clearly the main communications portal for the project. Regular news posts keep participants updated on the project's progress and the participant contribution page discussed in 4.3.3, above, is updated daily. The six newsletters that have been created since

2008 are informative and designed for volunteers and the general public. At the end of the seven year project, an online Atlas will by created, and a hardcopy version is also envisioned. No peer-reviewed articles using data from the project are listed on the site but these could be expected following completion of the data collection phase.

4.3.6. Current Status

The 2011 final report of the BCBBA project in BC's Columbia Basin region provides an indication of the success of the project to date. The report provides a table with province-wide statistics and statistics for the Columbia Basin region in the south-east of the province[8]. Of the 500 10km x 10km cells in the Columbia Basin, 200 were surveyed in 2010, and over the three year period of 2008-2010, 485 of the 500 cells were surveyed. Over the same three years (2008-2010), 1112 volunteers have provided 29,500 hours of volunteer effort, generating 152,341 breeding evidence records province-wide. 11,340 point counts in 941 squares were also recorded. In the Columbia Basin, professional ornithologists were contracted to complete point counts in priority squares (Davidson 2011), demonstrating the limits to volunteer labour when an entire landscape (in this case a rugged and remote landscape) must be surveyed. Analysis of Ontario Atlas data indicates that at least 15 point counts per square are necessary to include the square in provincial relative abundance estimation; much effort over the last two years of the project will focus on point counts (Di Corrado 2011). In response to the need to focus efforts on completing all squares within the five-year project timeline, customized tools were developed: the Data and Maps menu on the BCBBA website includes a query tool that produces summary tables indicating which squares have less than 15 point counts (../bcdata/maps.jsp). Bird Studies Canada's NatureCounts website (http://www.birdscanada.org/birdmon/default/datasets.jsp?project=bcbba accessed 19 January 2012) shows 203,014 raw breeding records for 2008-2012.

The BCBBA continues to receive significant funding support from provincial agencies including the Habitat Acquisition Trust Foundation and the BC Hydro Fish & Wildlife Compensation Program for the Columbia Basin, from the Baillie Fund, a private foundation. See

[8] The BCBBA received a grant from the Fish & Wildlife Compensation Program that had a reporting requirement, so a report was prepared detailing work in this region of the province. This sub-provincial report is discussed here because the higher level of detail it provides offers an insight into the logistics of the project.

the 10 April 2011 funding announcements at
http://www.birdatlas.bc.ca/bcdata/newsarchives.jsp?lang=en (accessed 19 January 2012).

Overall qualitative rating (1 poor to 5 excellent):

Project Management

Rating: 5. Partnership between NGOs and government increases use of data for science, management, education.

Protocol

Rating: 5. Study design is structured to ensure a sufficient level of counts across the entire province, not just those areas that can be easily reached by volunteers (like the CBC).

Volunteers

Rating: 5. During the first three years of the project (2008-2010), 1112 volunteers provided 29,500 hours of volunteer effort

Data management

Rating: 5. Bird Studies Canada hosts the BC BBA web site and manages the data portal. Data analysis, including GIS analysis, is provided by BSC as well. Data can be downloaded via the BSC site.

Communications

Rating: 4. Communications to date have primarily been used to recruit volunteers and to share information between project leadership and volunteers. Spring and fall update newsletters have been produced as well. The true impact of communications won't be known until the project is completed and the book published in 2014.

4.4. eBird

URL http://www.ebird.org (accessed 20 January 2012)

In their paper describing the eBird program, Sullivan *et al.* (2009) provide a number of reasons why birds are the favourite topic of conservation citizen science, including the diversity (nearly 10,000 species) and distribution of birds (all terrestrial and most aquatic ecosystems), the linkages between birds and biotic processes at many levels, the conspicuous behaviour and morphology of birds, their spectacular migrations, and the fact that birds are frequently encountered and enjoyed by people. Birds are typically non-threatening and have long been used to for food, clothing, as danger sensors ("canary in a coal mine"), for hunting, and to deliver messages. One writer captured the human connection with birds well when he said "there is nothing to worry about when you hear birds singing. It is when they are silent that you need to worry".

eBird takes the volunteer survey to another level, for instead of requesting volunteer involvement once a year, they encourage volunteers to contribute each time they raise their binoculars to observe a bird. Sightings are accepted from throughout the Western Hemisphere and New Zealand. The intended uses for the eBird database include: visualizing seasonal distribution changes; monitoring avian range changes; differential migration timing; priority species conservation; delineating migration timing for conservation management; providing data for decision-support tools; and modeling relative abundance.

4.4.1. Project Management

eBird is led by an academic and NGO partnership between the Cornell Lab of Ornithology (CLO) and the U.S. National Audubon society. It is semi-decentralized, working with regional partners that are free to take steps to ensure local relevance and to engage local audiences through customized portals. Underlying the customizations is a standardized database and application infrastructure so that the data is consistent across political and geographical boundaries.

4.4.2. Protocol

Sullivan *et al*. (2009) provides a detailed description of the protocol, and the eBird website provides a clear overview (../content/ebird/about). Essentially, eBird provides a web interface for participants to upload observations of species presence or absence by completing regional checklists. The site's tutorial (../content/ebird/about/tutorial) further describes the process as having four main steps: 1) enter birding location; 2) enter birding method (what kind of birding was done); 3) enter what birds were seen or heard; and 4) confirm. The interface provides tools for each step, including an interactive map tool for step 1. The second step, the birding method page, includes radio buttons for four protocols (traveling, stationary, incidental or other, the last of which has a drop down menu with random and specific options), and control boxes for entering date, start time, duration, distance, and party size (see section 3.1.vi, above).

Unusual records are flagged and users are prompted to confirm them once again. These records will be reviewed by a local expert. Users can also query the database of contributed observations and view results with the same web application. The site provides useful tools to the birder, including the ability to store their personal bird sighting lists on the cloud.

4.4.3. Volunteers

Although it builds on the solid citizen science foundation constructed by the CBC, Audubon, and the CLO, and their volunteer networks, eBird is a creature of the web and makes significant use of user-centred design principles to recruit and retain volunteers. In particular, eBird software provides useful tools for users – especially the technology for users to generate a range of bird lists from their uploaded data. Most bird watchers (also called birders) maintain lists of the birds they have observed, including life lists (all birds) and lists of birds in a given year or continent: eBird automates list creating and makes them available over the internet. The web site makes use of other Web 2.0 features, like lists of top contributors and contributors of first records of bird observations in a province or state. Another novel participant recognition method is the editor of the month: this provides a means to profile an individual, as well as adding more voices and content to the site. The site is available in English, Spanish and French.

4.4.4. Data Management and Analysis

Data is uploaded to regional portals that are managed by project partners, filtered and verified, and then integrated with the overall eBird database and application infrastructure. Data are stored in a secure facility, archived daily, and accessible to anyone. The data are also integrated with the Avian Knowledge Network (AKN), which consolidates observational data for the western hemisphere and feeds data into the Global Biodiversity Information Facility (GBIF) and other international data systems (See Kelling *et al.* 2009 for a description of the AKN data warehouse). The project is therefore an example of thinking globally and acting locally, as the method allows for local ownership and promotion of eBird, as well as providing data visualization and analysis at the hemispheric and even global scales.

In regards to public data accessibility, I was able to easily download eBird data via Bird Studies Canada's NatureCount website at http://www.birdscanada.org/birdmon/default/searchquery.jsp (accessed 20 January 2012). The data access policy is described online at http://www.birdscanada.org/birdmon/default/datasets.jsp?code=EBIRD&sec=policy (accessed 20 January 2012).

Sullivan *et al.* (2009) describes a two step verification process that includes automated and expert filtering: (1) instantaneous automated evaluation of submissions based on species count limits for a given date and location; and (2) a growing network of more than 500 regional editors composed of local experts who vet records flagged by the automated filters. The authors also identify some data quality concerns including: the uncertainty around birds that may have been present but were not detected; the range of observer skill levels; and the unstandardized locations used to identify travelling counts such as transects. There is also a geographical bias to the data since the birding community is not evenly distributed across the landscape, but instead is concentrated in areas of high human population density and low where human settlements are sparse.

4.4.5. Communications

The website is the main method of public communications. The site is very comprehensive, with many tools for participants (e.g. tutorials, graphic and geographic visualization tools). The homepage features a news feed, which appears to be very active: including three posts for January 2012 as of the 20th. There is also an eBird blog. Contributions to the scientific and popular literature are listed on the site at ../content/ebird/about/ebird-publications.

eBird also facilitates direct access of data and processes over the Internet via an application programming interface (API). This provides the means for application developers to feature eBird data in real-time.

4.4.6. Current Status

According to the websites' about page (../content/ebird/about), more than 1.5 million bird observations across North America were submitted in January, 2012. This makes eBird one of the world's fastest growing biodiversity data resources. In BC, 1,478,914 records were available for download on 20 January 2012. This number is in the same range of magnitude as the number of birds observed in the 2011 CBC in BC (see 4.1.6, above): eBird therefore is an exception to Dunn and Westin's (2008) observation that the magnitude of volunteer contributions is related to the length of time since a project's inception.

Overall qualitative rating (1 poor to 5 excellent):

Project Management

Rating: 5. Project management builds on CBC and other citizen science projects conducted by Audubon and the CLO. Sullivan *et al.* 2009 provides a published description of many elements of the project's management and user-centred design philosophy.

Protocol

Rating: 5. eBird allows users to choose between four protocols which range from more standardized methods like travelling or stationary counts, to random counts. Effort information is captured for observations as well.

Volunteers

Rating: 5. Volunteers are already contributing a similar amount of data annually as is the much longer running CBC project.

Data management

Rating: 5. Data is collected via a web portal, filtered, and then shared with the AKN data warehouse where it can be analysed in association with avian data from other sources and many environmental variables. Data was available for download.

Communications

Rating: 5. The project has been described in the literature (*ibid.*) and has a vibrant web site. It is too early to expect much impact on management or many published papers.

4.5. BC Cetacean Sightings Network (Wild Whales)

URL http://www.wildwhales.org (accessed 28 January 2012)

The B. Cetacean Sightings Network (BCCSN) is a project that collects public whale, dolphin and porpoise sightings via website, phone, email, and logbook methods. The project began with a one day public orca census in 1971 that solicited public participation via an advertising blitz and distribution of 17,000 surveys. Over 550 were returned, and the initial estimate of 550 individual orcas proved to be very accurate. The public continued to report sightings of whales, dolphins, porpoises and sea turtles in BC to both the Pacific Biological

Station in Nanaimo and the Vancouver Aquarium. In 1999, the BCCSN was established to centralize data and maintain a standardized data schema. The BCCSN website claims over 3000 observers and 40,000 records. Data have been used for academic research, government management, and NGO advocacy. See ../about-wild-whales/ and ../how-sightings-are-used/ .

4.5.1. Project Management

The BCCSN is a partnership of the Vancouver Aquarium Marine Science Centre (VAMSC), Department of Fisheries and Oceans Canada (DFO), and the Government of Canada Habitat Stewardship Program for Species at Risk.

4.5.2. Protocol

Registered users can enter observations at any time via the website. Upon logging in, a contributor can view a summary of her personal sightings or enter a new observation. An observation is entered in two steps. The first step consists of location (coordinates are calculated by moving a marker on a Google Map or by entering data directly in lat/long fields, and a description such as Point Atkinson), date and time, and weather (sea state plus wind speed). The second step consists of selecting a species and sighting platform information. ../sightings/step2.php. Species are chosen from a list (each species choice includes a picture, brief description, and link to more information), and augmented by choosing identification certainty (certain, probable, possible, uncertain), number of animals (exact, approximate, range buttons), and animal behaviour, and by uploading photos or videos. There is also an option to select how the observer heard of the BCCSN (../sightings/step3.php). Observations can also be contributed via phone or email.

As well as accepting ad hoc public sightings, the BCCSN has also developed a log book system. Building on the long-standing nautical tradition of maintaining logs to regularly document a voyage, the BCCSN designed and produced hard copy log books to distribute to regular contributors. Coastal mariners, such as tug boat captains, fishermen, whale watching guides, BC Ferries personnel and recreational boaters, use these books to maintain information about sightings. Pages from these books are then sent back to the BCCSN at the observer's convenience; the pages are carbon-copied so the observer can keep their records (../logbook-program/).

4.5.3. Volunteers

Cetaceans appeal to people: one only has to travel on a BC ferry and watch the response of the travelling public when an announcement comes on the loudspeaker about a pod of orcas off the starboard bow to appreciate this. Their huge size, graceful movement and behaviour, and generally non-threatening nature (with the exception of Moby Dick) are reasons for their public appeal; reports of their intelligence and their telegenic style on T.V. shows such as 'Flipper' add to our wonder at their physical appearance. Greenpeace nurtured this public interest in their campaigns to end whaling, and demonstrated clearly that the public were motivated to help recover cetaceans to more sustainable population levels. People will go far out of their way to view whales and will gladly report sightings to an agency that is actively working to sustain them. The BCCSN builds on this underlying interest in a number of ways. First, they have a very active outreach programme, providing presentations 'to thousands of British Columbians at schools, community groups, professional associations, and festivals throughout the year.' (../about-wild-whales). See also http://wildwhales.cultivate.it/wp-content/uploads/2011/07/Appendix-1-Wild-whales-program-information.pdf (accessed 28 January 2012). They helped to develop the Be Whale Wise Marine Wildlife Guidelines for Boaters, Paddlers and Viewers (Revised 2006 - ../whale-watching-guidelines/). Finally, they have used the user-centred design approach, especially on their website and logbooks. Regular news posts (see communications section below) help with retention by highlighting interesting observations and by demonstrating that the data is being put to good use. Frequent reporters of sightings are provided with a map of their sightings as an added incentive to continue participating; for instance, a list of the top 20 observers of 2011 was in preparation on according to a 5 January 2012 news post (../2012/01/2011-sightings-part-2/). The BCCSN has an alternate name, Wild Whales, which also demonstrates a knack for user-friendliness.

4.5.4. Data Management and Analysis

Whales are relatively easy to recognize and stand out clearly against their aquatic habitat, at least when on the surface, so classification and sightability data quality issues are relatively insignificant for this group of animals. To further reduce taxonomic errors, the web site provides a guide to recognizing cetacean species. The BCCSN also responds to some rare sightings by sending out a field crew to confirm.

The database is used internally by project partners to better understand cetacean ecology and to assist with marine species conservation, including the designation of Marine Protected Areas. External researchers may also be granted access to data: the organization receives 7 to 10 data requests a year which are reviewed by experts within VAMSC and DFO and approved based on scientific merit. One such study listed on the site was an evaluation of cetacean abundance based on sightings data, begun by SFU graduate student Nicole Koshure in 2007.

The BCCSN recognizes that the sightings data is biased by non-standardized observer effort. This makes it challenging to determine if areas of high sightings contributions are due to high numbers of observers or high numbers of cetaceans and sea turtles. The BCCSN is currently investigating ways to include effort data to standardize the observations, making them more useful for analyzing trends in cetacean abundance and distribution (../how-sightings-are-used/).

4.5.5. Communications

The project website and public presentations are the main communication methods. The website provides a range of information on the goals of the project and resources for conservation, education, and species identification. The website also serves as a project blog: the homepage includes the first few lines of the latest story, hyperlink titles to three other recent stories, and a link to the news archive (../news-archive/). 18 stories were posted in 2011. The site uses a set of icons to label news posts as stories about whale or turtle sightings, reviews of scientific reports, threats to species (such as entanglement), news from other jurisdictions, or general news (including fund raising appeals).

The next public event is also listed on the homepage; this links to the public presentations for the month ahead at ../upcoming-events/. When I visited the site on the 28^{th} of January 2012, this page listed five public events on a Vancouver Island public outreach tour during the period of Feb 7 to Feb 17, 2012.

4.5.6. Current Status

The January 5, 2012 news post reports that the program continues to grow. As of that date, the database included 65,000 records of 23 whale species and 3 sea turtle species. The Vancouver Island public outreach tour and recent news posts also demonstrate that the initiative remains viable and active.

Overall qualitative rating (1 poor to 5 excellent):

Project Management

Rating: 5. Effective project management is demonstrated by large numbers of records collected, good spatial extent of records along the BC coastline, and history dating back to 1971.

Protocol

Rating: 5. Ad hoc sightings and log book recordings are both supported. The former provides a simple and immediate method to contribute to the project. The latter method cleverly builds upon the maritime tradition of carefully logging activities and provides an opportunity to capture effort as well as observations.

Volunteers

Rating: 5. The project is making significant efforts to continue to recruit volunteers and offers prizes to retain existing volunteers. Evidence of user-centred design on project web site.

Data management

Rating: 4. Data is collected via a web portal, and, in the case of rare or unexpected sightings, confirmed in the field. Data management is provided by the VAMBC. Some data sharing is permitted – but only a few researchers are able to access the data each year. Less restrictive data sharing would increase the value of the project to conservation biology.

Communications

Rating: 4. The project website remains up to date: on my last visit to the site on 6 April 2013, the latest post on the front page was from 13 March 2013. As was the case when I first checked the site in January 2012, a series of public presentations are planned along the coast. There is little evidence that scientific publications or improved conservation management is flowing from the project: no papers and few management actions are listed on the site.

4.6. BC Butterfly Atlas

URL: http://www.bcbutterflyatlas.ca (accessed 5 April 2013);

http://www.inaturalist.org/projects/british-columbia-butterfly-atlas (accessed 28 January 2012)

The BC Butterfly Atlas was launched in the spring of 2012 to 'harness the efforts of both professional biologists and citizen naturalists to document the distribution and abundance of butterflies across British Columbia.' (DRAFT Instructions for Atlasers. BCBA 2011). Important objectives include identifying rare and common species, creating a snap shot in time to compare with past and future surveys, and to provide information for conservation planning.

4.6.1. Protocol

The BCBA protocol allows three types of observations: incidental observations, monitoring of one or more individual sites and more structured observations (../about). The latter will build on the BC Breeding Bird Atlas grid method, including using the same 10 km x 10 km squares; a minimum survey effort within each square is 20 hours. A downloadable data form has been provided for each observation type (../instructions-forms – all revised 18 January 2013). All observations will require six pieces of information:

1. Date and time of observation
2. Name of the observer(s) (incl. contact info),
3. Butterfly species observed,
4. Identification code (sighting, photograph, caught/released, road-killed, voucher specimen)
5. The number seen, and
6. Location (lat/long or UTM coordinates plus UTM zone)

Photographs can also be submitted; these can be used by the project managers to confirm taxonomy. Observations can be contributed via mail, email, or the project website. Participants are requested to not collect any specimens of rare species.

4.6.2. Organization

The project is led by Patrick Lilley of Raincoast Applied Ecology (../about). The project's advisory committee includes professional entomologists and a wildlife biologist, academics, and the BC government's invertebrate specialist (../advisory-committee). Sponsors include the BC Habitat Conservation Trust Fund and Environment Canada's Habitat Stewardship Program for Species at Risk, and partners & in-kind supporters include NGOs (Bird Studies

Canada and the South Coast Conservation Program), BC government agencies (Conservation Data Centre and the Royal BC Museum) and the Spencer Entomological Collection at UBC (../sponsors-partners). Lilley reports that the project has been able to access historical datasets to add to the project database (Lilley 2013).

4.6.3. Volunteers

According to Lilley, the BCBA has "39 officially registered participants, although the number of contributors through eButterfly is up to 124 users from BC" (Lilley 2013). 925 records entered in 2012. Taking another page from the BC Breeding Bird Atlas, the BCBA team is soliciting engagement in the project through BC Nature and its members in local naturalist groups (../news). Resources provided to volunteers on the web site include: atlasser materials (instructions & forms, atlassing guidelines, and maps), identification aides (recommended books, photo plates, and regional ID cards), brochures & factsheets, reports and publications, and links to other sites (see the Resources menu on the home page). The maps, which include atlas region maps in JPG format, topographic maps of atlas squares in PDF format, an interactive map of atlas squares (ArcIMS internet map service with a JavaScript mapviewer), and downloadable spatial data files of atlas squares, blocks, and regions (KML and SHP formats), were all provided by Bird Studies Canada and its BC Breeding Bird Atlas partners (../maps). Volunteers must register to contribute information to the project.

4.6.4. Data Management and Analysis

In January 2012 the project had a draft site on iNaturalist.org (http://www.inaturalist.org/projects/british-columbia-butterfly-atlas (accessed 28 January 2012), a free resource operated in the US that provides a web portal and data management for naturalists and others. Over the past year, the decision was made to partner with eButterfly (www.ebutterfly.ca accessed 5 April 2013) instead for data management. eButterfly is a new project that began in Canada and has recently expanded to the US (http://www.ebutterfly.ca/contents/Frequently_Asked_Questions 5 April 2013). It is led by Jeremy T. Kerr of the Canadian Facility for Ecoinformatics Research (CFER) at the University of Ottawa (www.macroecology.ca accessed 5 April 2013). This partnership provides the BCBA with important data management tools such as online data entry and interactive web maps of the Atlas, and ensures that the BC data will be pooled with data from other sources to conduct continent wide analyses. The interactive web maps show squares that have been surveyed, and by clicking on these squares one can see detailed records, including the name of the volunteer. The iNaturalist site meanwhile is not linked to the main website and shows no records since 2011, so is probably abandoned.

4.6.5. Communications

The project website was not accessible when I first visited on 28 January 2012. Some stories about the project in various newsletters were found via a Google search the same day:

- Comox Valley Naturalists http://comoxvalleynaturalist.bc.ca/2011/05/bc-nature-enews-april-2011/
- Boreus, Newsletter of the Entomological Society of British Columbia, June 2011, Volume 31 (1). http://www.sfu.ca/biology/esbc/boreus/vol_31_1.pdf
- BC Breeding Bird Atlas Newsletter Summer 2011. http://www.birdatlas.bc.ca/download/newsletter_summer11.pdf
- FORREX Conservation Biology e-newsletter, August 2011. http://thegreenpages.ca/bc/2011/08/forrex-conservation-biology-enewsletter-august-2011/

(All accessed 28 January 2012)

When I next visited the site in April 2013, it was online and very user-friendly. The front page includes a twitter feed which indicates the project has adopted social media. The News section of the site includes a single post: a copy of an article written by Lilley and published in the spring 2012 edition of BC nature (../news). One has the option to sign up for an eNewsletter which apparently is published quarterly, although no past issues could be found (http://bcbutterflyatlas.us4.list-manage.com/subscribe?u=d9ed12ff73684ed4fc7f5fb29&id=3a257f322e accessed 6 April 2013).

4.6.6. Current Status

The BCBA has advanced considerably over the period January 2012 to April 2013. As mentioned above, in January 2012 the website was down and a draft iNaturalist.org application with just a few points, all of which were contributed by the project leader, comprised the project's web presence. In April 2013, the BCBA site was live and 1260 records (including both historical and 2012 records) were contributed by December 2012 (http://www.ontarioinsects.org/bcbutterflyatlas/ accessed 6 April 2013). The project has a diversity of sponsors and partners in academia, government, non-government, and private sectors. Partnering with Bird Studies Canada and eButterfly has provided the project with useful tools (such as BSC's digital and online maps) and sophisticated data management (via the Canadian Facility for Ecoinformatics Research, eButterfly's parent organization).

Overall qualitative rating (1 poor to 5 excellent):

Project Management

Rating: 5. After only one year in existence, the BCBA now has a credible project underway: diverse funding, partnerships with organizations that bring citizen science expertise (BSC) and data management expertise (CFER) to the project; over nine hundred observations were gathered across the province in 2012 (although mainly in and around major human population centres); and historical datasets have been shared with the project.

Protocol

Rating: 4. The BCBA has more or less adopted protocols developed for bird citizen science projects, including point counts, repeated counts at a single location, and counts within 10km x 10km squares. It will be interesting to see if these winged creatures can indeed be successfully surveyed using methods developed for ornithology: perhaps not only birds of a feather, but also non-feathered winged-creatures, fly together.

Volunteers

Rating: 3. The project has recruited 39 participants in the past year. It is too early to evaluate retention.

Data management

Rating: 4. Data is collected via a web portal, and data is managed by eButterfly and CFER. This should ensure that the data is available for analysis at provincial, national, and international scales. There is no way to download data from the site, however.

Communications

Rating: 4. The project website is up to date: the twitter feed seems quite active with at least 4 posts in the last month. Lilley did a good job getting the word out through newsletters from various organizations: now he needs to ensure that the promised quarterly eNewsletters keep flowing. It will likely be a while before data collected by this project makes its way into the literature or has any significant management impact.

4.7. BC Shorekeepers

URL: http://www.keepersweb.org/Shorekeepers/index.htm (accessed 2 February 2012)

The BC Shorekeepers project emerged from an expansion of the mandate for Canada's Department of Fisheries and Oceans in a time of reduced government spending on conservation. Canada's Ocean Act of 1997 requires DFO to use an ecosystem-based approach to managing ocean resources, a significant change from the traditional practice of monitoring individual (primarily economic) fish species in isolation. Initiating an integrated approach that considered many more species and their interactions placed new demands on DFO's scientific staff without adequate expanded resources. DFO also recognized that local people and communities desired more meaningful involvement in decision-making. Creating the Shorekeepers project provided a way for people to become involved in field science, and thus gain the knowledge and understanding of marine ecosystems needed to better enable participation in decision-making, while also contributing data to DFO's new ecosystem-approach to scientific evidence-based planning.

4.7.1. Project Management

DFO leads the project. The first step in preparing to survey an area is contacting a DFO representative. The department also organizes training and maintains the database. Kevin Conley is listed as the contact for the project at http://www.cmnbc.ca/atlas_gallery/shorekeepers-atlas (accessed 2 Feb 2012).

4.7.2. Protocol

The Shorekeepers' protocol is relatively elaborate. DFO developed a Shorekeepers' Guide (Jamieson et al. 1999; available at ../Shorekeepers/Guide/index.htm) modeled on the Streamkeeper's Program and drawing from the DFO Coastal and Estuarine Fish Habitat Description and Assessment Manual of 1993. This guide has an introduction, three modules (mapping and surveying intertidal habitats; information management; and training curriculum for instructors) and four multi-page data forms. The first module alone is over 100 pages in length.

The goal was to create a protocol to 'enable interested non-professional individuals and community groups to obtain standardized, credible data over time from a specific physical site – and from these to document and evaluate the nature of change, if any, that is occurring (*ibid*.: i).' Both physical substrate characteristics and biological features are used to define and map habitats, and then to sample those habitats to estimate species abundance and diversity. The Guide includes a mapping and survey module, a data management procedure, and a curriculum for training leaders about the survey protocol and data management.

The surveys are done in spring or summer months when tides are low during the day. The surveys are primarily directed towards the intertidal zone but information on the lands adjacent is also collected. Participants are encouraged to take a three-day training course: each 5 or 6 person survey team should be lead by a trained member.

4.7.3. Volunteers

Volunteers are recruited through the project website. Volunteer resources, in particular DFO contact information and the protocol document, are also available there. The site is a typical top-down government website and eschews any semblance of user-focussed design or Web 2.0 characteristics: it does not recognize volunteers in any way or provide any news, updates, or discussion forums.

4.7.4. Data Management and Analysis

Volunteers complete paper forms; the data is then entered manually into a downloadable application build on MS Access. Data is then uploaded over the Internet by authenticated users (volunteers with a username and password) to a database which is maintained by DFO. There is no filtering of data; volunteers must catch any errors during data entry (Rasmussen 2011). Data is can be browsed online through an internet mapping application hosted by the Community Mapping Network (CMN) site at http://www.cmnbc.ca/atlas_gallery/shorekeepers-atlas (accessed 2 February 2012) (see 9, below for more information on the CMN).

4.7.5. Communications

Project communications include the website and direct communications between DFO staff and volunteers. New volunteers must contact a DFO representative to learn more about the project and to become involved. The Shorekeepers Atlas on the CMN site (direct link http://204.244.79.23/mapguide2010/shorekeepers/main.php accessed 2 February 2012) uses

MapGuide2010 to display data geographically. Surveys are represented as points with linked reports; however, when I accessed I was unable to access reports for the study locations I checked (Galiano and Gabriola Islands).

4.7.6. Current Status

The project appears to be the victim of federal government cut-backs as funds have not been committed to keep the project current. Communications with DFO in 2011 indicated that the organization was "still in the decision-making process as to what it's commitments will be going forward" (Rasmussen 2011); in April 2013 the project was "still on life support… we have not committed to the expense to upgrade the data for that [CMN] site" (Rasmussen 2013). In recent years activity has been limited to the southern coast, including Saanich Inlet, the Southern Gulf Islands, White Rock and the Victoria area (Conley 2012). The interactive Shorekeepers Atlas described above only shows data to 2007. The project's main web site has not been updated since 2006.

Overall qualitative rating (1 poor to 5 excellent):

<u>Project Management</u>

Rating: 2. The project got off to a good start with the careful and thorough development of a protocol and training manual. However, the project been "on life support" for two years.

<u>Protocol</u>

Rating: 4. The protocol was designed to produce scientifically credible data and is well documented. As the protocol is relatively complex, training is required: this is both costly to deliver and a barrier to volunteer involvement. Introducing multiple protocols, as the birders and lepidopterists have done, could help: for instance, allowing for simple point observations of eel grass or tide pools containing fish

<u>Volunteers</u>

Rating: 2. Training has not been offered for several years and in recent years little data has been collected.

<u>Data management</u>

Rating: 2. Volunteers enter data on forms and then enter them into a custom application that they can request from DFO. Data is then uploaded to the DFO site. This method requires that each group has MS Access installed and is able to download and run the application, creating barriers for contribution. Online data portals remove this constraint. Data can be browsed via the CMN site, but it cannot be downloaded. Less restrictive data sharing would increase the value of the project to conservation biology.

Communications

Rating: 2. The project website is many years out of date, and I was unable to find any recent updates on the project through Google searches. My correspondence with DFO staff involved in the indicated that the project was more or less on hold: the project managers should update the website with a note about the current status of the project.

4.8. Pacific Streamkeepers Federation

URL: http://www.pskf.ca (accessed 2 February 2012)

The Streamkeepers program began in 1993, when the federal Department of Fisheries and Oceans received funds from the Fraser River Action Plan to develop the Streamkeepers Handbook and Modules. The Pacific Streamkeepers Federation (PSkF), an NGO, was founded in May 1995, and training of volunteers to use the Streamkeeper protocol began in 1996. Since that time thousands, of British Columbians have been trained to be Streamkeepers, and the PSkF continues to provide training support, coordination of effort, and cooperation amongst the groups as well as lending a larger voice to enhancement issues (see ../program/about.html and ../program/program.html).

The impetus for creation of the Pacific Streamkeepers was the decline of the salmon fishery (Justice 2007). Volunteers began to work on local stream enhancement in order to improve rearing habitat for these anadromous fish. Streamkeepers are also active in places such as the Kootenays where salmon no longer return, due to hydro-electric dams; in these areas, they are enhancing habitat for other salmonid species of conservation concern, including bull trout.

4.8.1. Project Management

The PSkF manages the project partnership with DFO and various independent local Streamkeeper societies.

4.8.2. Protocols

The Streamkeepers Handbook and Modules includes protocols for: introductory stream habitat surveys; advanced stream habitat surveys; water quality surveys; stream invertebrate surveys;

streamside planting; and juvenile fish trapping and identification. The handbook and associated data forms can be accessed from the website at ../publications/download.html. The PSkF works with community colleges and DFO to provide training through the province; a list of trainers are provided at ../program/trainers/index.html. DFO certifies the trainers, who then provide the training using the Streamkeepers curriculum. Two days of training is required for primary data collection protocols: modules 1 through 4 (introductory and advanced stream surveys, water quality surveys, and stream invertebrate surveys). Training is available across the province but can cost up to $170. Data collection in the field is done using data collection sheets associated with various modules.

4.8.3. Volunteers

The project has very effectively reached out to community groups across the province concerned with stream habitat conservation. Two Masters theses (available on the project website at ../program/new.html) have looked at volunteer involvement in the Streamkeepers. Justice (2007) considers volunteer involvement in fish habitat restoration across the province, while Peers (2007) provides a detailed assessment of communities of practice within three local Streamkeepers groups located in the Lower Mainland. Streamkeepers not only collect data about streams, they actively participate in restoration and stewardship activities as well. As such, they are close partners with government agencies responsible for habitat management and, as government funding declines, they play an increasing role in overall watershed management.

In regards to stream surveying, the volunteers must pay for their own training, but are provided protocol materials and forms for data collection in the field. Volunteers are also provided some insurance coverage through membership in the PSkF for their field activities (see ../ins/index.html). Participants download a data entry tool to enter and upload data to the Streamkeepers Central Database. The tool is designed to capture data gathered in the field using the data collection sheets and to reduce invalid data entry. The tool also supports data queries and report generation.

Besides the materials in support of data collection, many other resources are provided on the website. These include a series of stewardship documents, theses, and educational and outreach materials. Educational resources, such as colouring templates provided on the site at ../publications/sheets/index.html, indicate that the organization has a long-term volunteer recruitment strategy.

4.8.4. Data Management and Analysis

Volunteers collect data in the field using data forms and then upload the data via an authenticated web portal. The web portal and the central database were managed by DFO until recently (see 4.8.6 below). When contacted on 8 April 2013, the project coordinator stated that due to an update of DFO computers, the database was no longer supported, and a new data entry tool hosted by PSfK was undergoing beta testing (Morton 2013). This tool will enable "data harvesting" by other researchers while ensuring data quality (*ibid.*). At present, access to data via an internet mapping application is not available; however, recent posts on the PSkF message board suggest that this is something they are considering (see Morton's January 19th comment to Cipywnyk's January 18th post at http://disc.yourwebapps.com/Indices/198175.html accessed 2 February 2012)

4.8.5. Communications

The PSkF website provides a wealth of resources for stream inventory, stewardship, and restoration. User-centred design includes an active message board (a discussion forum) at http://disc.yourwebapps.com/Indices/198175.html (accessed 2 Feb 2012); 25 threads were posted from 17 Jan 2012 to 1 Feb 2012. This forum is available via an RSS feed. The PSkF hosts a biennial community stewardship workshop: the last was held in Campbell River, May 20-23, 2011 (see http://workshop.pskf.ca/ accessed 2 Feb 2012).

4.8.6. Current Status

When I revisited the site on 6 April 2013, I discovered that the data entry portal and central database are no longer hosted by DFO (see http://habitat.rhq.pac.dfo-mpo.gc.ca/pskf_decommissioned.html (accessed 6 April 2013). As noted in 4.8.4., above, the PSkF is in the process of transitioning to a new, in-house database which is intended to provide more data "harvesting". With the exception of the discussion forum, most of the project website's content is quite dated. The latest post on the What's New page at ../program/new.html was from 12 May 2009.

Overall qualitative rating (1 poor to 5 excellent):

Project Management

Rating: 4. The PSkF is both an organization formed to work with DFO to address fish habitat concerns and an umbrella agency for an affiliation of independent local organizations. As such it is a hybrid of top-down and bottom-up governance. This hybrid structure may provide the best of both models: protocols designed by experts, professional data management, and direct connection to resource managers on the one hand, and increased empowerment for citizens on the other. Too much reliance on DFO may cause serious problems as DFO's budget shrinks and mandate changes.

Protocol

Rating: 4. Many of the 14 protocols were designed to produce scientifically credible data and all are well documented.

Volunteers

Rating: 4. The website states that thousands of volunteers have been trained. It is hard to tell from the site how many of these have ever contributed to the project. Insurance is provided to volunteers.

Data management

Rating: 3. Data management is currently being transferred from DFO to PSfK. The new data entry tool, when deployed, will reportedly enable data downloads. No interactive web mapping of the data is provided at present.

Communications

Rating: 2. Most of the PSfK website is many years out of date.

4.9. Community Mapping Network

URL http://www.cmnbc.ca/ (accessed 5 Feb 2012)

The Community Mapping Network (CMN) was launched in 1998 with the goal of improving environmentally sustainable planning and management in BC by providing public access to natural resource information, maps and mapping information (../about-cmn) . Like the Streamkeepers and Shorekeepers projects, which are likewise partnerships between community groups, the private sector, and government, the CMN has the dual objectives of collecting the detailed ecological data needed for sustainable planning and providing education, information, and coordination to members of the public who wish to become more involved in planning and management. The Autodesk Mapguide interactive map services on the CMN integrate data from government and community groups. Some of the atlases on the CMN use older Mapguide software that is not supported on Mac computers and some popular modern browsers such as Firefox and Chrome; however, the organization is actively upgrading these to Mapguide Enterprise which is more widely supported (see ../software-information-downloads) . A number of the citizen science projects described in this paper have contributed data to the site, including BC FrogWatch and various local Streamkeepers surveys. As well as serving as a centralized warehouse of natural resource information, the CMN is involved in outreach, stewardship and conservation promotion, and training.

4.9.1. Project Management

The CMN is governed by a steering committee with representation from government (including Federal, BC, and local governments) and environmental NGOs (BC Conservation Foundation and a variety of local groups). The CMN had 35 active partner organizations in 2005. Brad Mason, DFO, and Rob Knight, BC Ministry of Water, Land and Air Protection were project coordinators then (../about-cmn, ../files/CMNSummaryReportMarch16_05_0.pdf) .

4.9.2. Protocol

The CMN developed a stream mapping protocol called sensitive habitat inventory mapping (SHIM, Mason and Knight 2002) and certifies trainers across the province. The sensitive habitats of interest are primarily aquatic, including watercourses, eelgrass beds, riparian areas, and wetlands. The protocols developed and promoted by CMN are intended to capture data that can be used in government mandated activities such as habitat referrals flowing from development applications. From the government's perspective, SHIM is an extension or augmentation of the work of professional scientific staff (../files/CMNSummaryReportMarch16_05_0.pdf).

The SHIM protocol can be accessed online at ../cmn/files/methods/SHIM_Methods.html. The protocol is divided into nine modules and four appendices. I could not find any upcoming training sessions: none are listed on the website at either ../watershed-education or ../workshops. No trainers are listed on the site.

4.9.3. Volunteers

Volunteers are recruited by partner community groups, and then trained in SHIM methods by trainers certified by the CMN. By 2005, thousands of volunteers had been trained in BC (../files/CMNSummaryReportMarch16_05_0.pdf). Two of the case studies in the 2005 Summary Report (*ibid.*) provide some descriptions of how volunteers participated in projects. Besides hosting SHIM data, the CMN's mapping site also accepts a range of conservation data from community-based groups. Each group is given a home page which is linked to a map.

4.9.4. Data Management and Analysis

The CMN site hosts an impressive array of projects. According to the homepage, 21% of these are species and habitat mapping projects, 19% are community mapping projects, 18% are community involvement projects, and 15% are environmental indicators and non-species projects. SHIM projects are accessed most by site users. Nearly 29,000 features on over 200 streams were SHIM mapped using a GPS in the field by 2005. Wildlife trees, wildlife observations, frog observations, and eelgrass mapping projects area are other significant contributions to the CMN. Each project has a homepage with a linked map. The homepage is designed in a standard format with a description section, a data section (which includes latest update date, whether the atlas allows data entry, web links, and attached files) a contact section, and a link to atlas section. The atlases themselves, including mapping software used, data layers displayed, and available tools, vary by project. The Fish Inventory Summary System (FISS) atlas page allows data contributions by authenticated users for instance (http://204.244.79.20/atlases/fiss/main.cfm accessed 5 February 2012).

The architecture of the site allows each project to be unique, but it also prevents holistic geospatial data representation. As each project exists on the site independently, it is not possible to analyze or visualize all data that might be on the site, but within different atlases, for a given area. There is also no mechanism in place to download the data files for a given project; the SHIM atlas has a tool with options to download as CSV but this was not operational (see Task list tool on the left of the toolbar at ../SHIM/. Most of the atlases on the site use Mapguide software: many of these rely on an older version of the software (Autodesk Mapguide) which requires a plug-in that is not supported on Mac computers or by many modern browsers such as Firefox and Chrome, further limiting the usefulness of the data archive (see ../software-information-downloads). Beginning in 2007, atlases were constructed using OpenSource

MapGuide Enterprise, which does support Mac and a wider range of browsers (../news/open-source-mapguide-enterprise).

4.9.5. Communications

The project homepage includes a feature project, a bar graph showing projects by type, a map of projects, a news feed, links to useful resources, and a place to sign up for the CMN Newsletter. The most recent news post was from the 13th of July 2010. The project website is built on the Drupal content management system (http://www.shim.bc.ca/ accessed 5 February 2012), which facilitates content updates, including changing featured sites, posting news stories, and adding new pages to accommodate new atlases. I was not able to locate an archive of past newsletters.

4.9.6. Current Status

In general, it appears that the project is ongoing, but at a lower level of activity than in the past. The SHIM atlas page (../atlas_gallery/sensitive-habitat-inventory-and-mapping-shim) reports that the latest data update was from 11 January 2012. The FISS site reports an update from December 2011 and a new Google fusion atlas (../atlas_gallery/fisheries-information-summary-system-data-entry-tool). Meanwhile, many atlases have not been ported from Autodesk Mapguide to OpenSource Mapguide Enterprise and so are not available to many users. The most recent news post was from July 2010 – and there were only two posts that year. No training courses or trainers are listed on the site. However, personal communication from Brad Mason (2011) indicates the project is ongoing, and a 2012 post by Rob Knight on the PSfK message board demonstrates that the project continues to be promoted by its founders (see http://disc.yourwebapps.com/discussion.cgi?disc=198175;article=6615;title=The%20Pacific%20Streamkeepers%20Federation accessed 5 February 2012).

Overall qualitative rating (1 poor to 5 excellent):

Project Management

Rating: 4. The project is lead by a DFO habitat enhancement branch scientist, Brad Mason, and Rob Knight, a retired BC Ministry of Environment biologist with an advisory board representing federal, provincial, regional and local governments and NGOs.

Protocol

Rating: 4. The SHIM protocol resembles the first four modules of the Streamkeepers module, with more emphasis on using GPS technology to capture accurate positions. Training is required.

Volunteers

Rating: 4. Many volunteers have been trained, but how many contribute?

Data management

Rating: 3. The CMN mapping application is slow and data cannot be downloaded.

Communications

Rating: 3. Most of the website is many years out of date. Data has been used for management but hasn't lead to any contributions to the literature.

4.10. NatureWatch

URL http://www.naturewatch.ca (accessed 5 February 2012)

NatureWatch was a citizen science initiative of Environment Canada, and comprises FrogWatch, IceWatch, PlantWatch, and WormWatch. The information gathered through NatureWatch is used to improve knowledge of the threats facing biodiversity, including climate change. It also provides an avenue for the public to 'act positively on nature's behalf' (homepage URL).

4.10.1. Project Management

Environment Canada's Ecological Monitoring and Assessment Network (EMAN) program developed the project: although the EMAN office has closed, Environment Canada continued to support NatureWatch (Doyle 2011). As of April 2013, the project was managed by NatureCanada, an NGO (see http://www.naturecanada.ca/cwn_naturewatch.asp (accessed 5 February 2012). Regional coordinators for the PlantWatch program are listed at ../plantwatch/program_coordinators.html; the BC coordinator was listed as Dawn Hanna on 6 April 2013.

4.10.2. Protocols

The NatureWatch protocols 'cater to beginner and expert alike', 'are quick and easy to follow', and 'scientifically rigorous' (homepage). Protocols and related materials are provided on the website and vary for each of the four subprojects. The FrogWatch pages provide material customized for different provinces. The BC page (../frogwatch/bc/intro.html) provides links to resources to help identify frog species in the field, including photos and call recordings. IceWatch (../icewatch), PlantWatch (../plantwatch), and WormWatch (../wormwatch) homepages each provide links to identification and survey planning resources. The PlantWatch page also provides a downloadable data form, while the IceWatch page provides some safety reminders. All subprograms provide a portal for submitting observations.

4.10.3. Volunteers

Volunteers are recruited through the web page. Over 2000 volunteers contributed to the project during the EMAN era (Doyle, pers. comm. 2011). Educational materials are provided online. Volunteer retention is supported by providing online access to results for each subproject, including interactive maps, downloadable data and, in some cases, assessment reports (see communications, below). No other resources are provided.

4.10.4. Data Management and Analysis

Volunteers must register before they can submit data. Data is submitted via a single portal and managed by Nature Canada. Submitted data can be viewed on an interactive map application built on Google Maps; for instance see ../map_of_observations.php?language=english&WatchProgram=FrogWatch (maps for the other sub-projects can be accessed by replacing Plant with Ice, Worm, or Frog in the URL string). Observations can also be downloaded in CSV format from ../download.html.

4.10.5. Communications

The project website is the sole means of communications. Visitors here can find resources for identifying these four components of the natural world, create an account and upload data. They can also view results from each project: a ../<project>/view_results.html page is provided for the plant, frog, and ice subprojects with links to an interactive web map (built on Google Maps), an assessment using submitted data, and related publications, if any. The PlantWatch results page includes a spring flowering date assessment of PlantWatch data for Churchill, Manitoba and Northern Labrador: see ../plantwatch/pw_north_assessment_spring_flowering_dates/index.html. An assessment of trends in frog and toad data for Ontario is available at ../frogwatch/assessments/trends_in_ontario_populations/index.html. Assessments in graph form for IceWatch water bodies is here: ../icewatch/icewatch.phtml?language=english. Only the interactive map is available for the WormWatch project. Observation data for all four subprojects can be downloaded in CSV format from ../download.html. News stories to May 2007 are posted at ../news.html. A print tool is available to print maps.

4.10.6. Current Status

Although Environment Canada's EMAN office has been closed, the project continues: Nature Canada now hosts the project. The website shows little sign of recent activity: the latest news posting is from 1 May 2007. However people are still uploading observations. I downloaded data for all projects in February 2012 and found recent observations for all four projects: the most recent observation for FrogWatch was from 20 November 2011, for IceWatch was 20 January 2012, for WormWatch was 23 September 2011, and for PlantWatch was 9 September 2011.

Overall qualitative rating (1 poor to 5 excellent):

<u>Project Management</u>
Rating: 3. The projects started well with strong support from the EMAN office, but once that was closed down, project management has been significantly reduced.

<u>Protocol</u>
Rating: 4. The protocols are all easy to follow and the data entry portals are straightforward to use.

<u>Volunteers</u>
Rating: 3. Although over 2000 volunteers contributed during the EMAN era, little ongoing effort is being made to attract or retain volunteers.

<u>Data management</u>
Rating: 3. It is still possible to upload, view, and download data. However, it is not clear that the data is being analysed in any way.

<u>Communications</u>
Rating: 2. Most of the website is many years out of date. Nothing on the site relates the changes to project management or the purpose of the site. There is no indication that the data has been used in any recent publications or management actions.

4.11. BC FrogWatch

URL http://www.env.gov.bc.ca/wld/frogwatch/ (accessed 14 February 2012)

BC FrogWatch (BCFW) is a response to the global decline of amphibians: the public is encouraged to collect and upload information on frogs, toads, salamanders, and turtles in BC. The information will be collated, mapped, and shared with biologists, naturalists, educators, and the general public to assist in conservation and recovery of amphibians and their habitat. The BCFW website provides resources such as species factsheets, photos, and frog and toad call recordings to assist in identification. It also contains information on amphibian ecology for people interested in learning more about these animals.

4.11.1. Project Management

BCFW is lead by Purnima Govindarajulu, a biologist with BC Ministry of Environment. Project partners include: the Habitat Conservation Trust Fund (HCTF), the BC Conservation Data Centre, Thompson Rivers University and the Ecological Monitoring and Assessment Network (EMAN). BCFW works closely with the Federation of BC naturalists (BC Nature) and the Community Mapping Network.

4.11.2. Protocol

The project has developed two protocols for frog watching: incidental sightings and long-term monitoring, and provides forms for each to structure data (see ../frogwatching/docs/Datasheet-IncidentalSightingForm.pdf and ../frogwatching/docs/Datasheet-LongTermMonitoring.pdf). The incidental sightings form includes sections on site location (date, time, longitude / latitude or UTM coordinates and zone), observer information, weather conditions, and animal observations. The long-term monitoring form includes survey method, habitat description and survey conditions (weather plus background noise for call surveys) as well as location, observer observation, and animal observations. For incidental reports, the fields required for data entry are observation date, observer or group name, email, species common name, and count. The long-term monitoring form has site name, observer or group name, email, and species common name as minimum requirements. The forms state that observations should be entered online at http://cmnmaps.ca/mapguide2011/frogwatch/index.php (accessed 14

February 2012); however this site was not active on 6 April 2013. However, another page on the site (../frogwatching/report/) provides a link to the BC Wildlife Species Inventory Wildlife Sighting Form at http://a100.gov.bc.ca/pub/cwi/spi_wsf.MainPage (accessed 6 April 2013).

4.11.3. Volunteers

The project home page lists government and academic partners, and linkages with NGOs including the Federation of BC Naturalists (BC Nature), CMN, BC Wetlandkeepers, and BC Wild. The involvement of NGOs whose interests align with the project goals indicates that the project intends to tap existing volunteer networks to recruit participants. I was able to find at least one call for volunteers in a NGO blog: see The Land Conservancy blog post at http://blog.conservancy.bc.ca/2010/06/frogwatch-2010/ (accessed 14 February 2012).

4.11.4. Data Management and Analysis

The BC FrogWatch Atlas on the CMN is currently under redevelopment using MapGuide Enterprise. The current atlas homepage (http://www.cmnbc.ca/atlas_gallery/frogwatch-bc , accessed 7April 2013), had a note stating that the FrogWatch Atlas was being updated and that requests for new data entry accounts was on hold, and those with existing accounts should also hold off on uploads for the time being The interactive map (http://shim.bc.ca/atlases/frog/main.htm accessed 7 April 2013) runs on AutoDesk Mapguide software and thus is limited to only some browsers and operating systems. The web map displays many locations for frogs and toad, salamander, and turtle species across BC; however, the locations I checked for the Kootenay region were all contributed in the 1990s.

4.11.5. Communications

Communications include the project home page and the CMN atlas pages online. Participating NGOs have also communicated about the project to their members, for instance see http://www.cathedralgrove.eu/text/02-Protest-5.htm , http://www.bakercreek.org/Frog-Watch.html and http://fraservalleyconservancy.ca/about/fvc-programs/amphibian-protection/ (all accessed 14 February 2012). BC Ministry of Environment staff have also given public presentations about the project, e.g. http://www.terracedaily.ca/go5638e/BC_Frog_Watch_Talk (accessed 14 February 2012). The project has a Facebook page at http://www.facebook.com/pages/BC-Frogwatch/224595914254291 which was blank when I viewed it on 14 February 2012 and again on 7 April, 2013.

There is also some indication of confusion between this project and the national FrogWatch project described in section 4.10, above. For instance, the NGO Okanagan Conservation Planning website provides a link to "Frog Watch British Columbia" which actually points to Nature Canada's NatureWatch site (see http://okcp.ca/index.php?option=com_mtree&task=viewlink&link_id=164&Itemid=487 accessed 7 April 2013).

4.11.6. *Current Status*

The project is currently active and the linkages with NGOs as discussed in the volunteer and communications sections above demonstrate that there is some grass-roots support. However, the lack of activity on both the web mapping application and Facebook page indicates that level of activity is low.

Overall qualitative rating (1 poor to 5 excellent):

Project Management

Rating: 2. The project has been in hiatus for some time. More active partnerships with academia and the NGO sector could help to galvanize this project.

Protocol

Rating: 3. Providing options for both incidental sightings and long-term monitoring should facilitate contributions, and enable researchers to study both the distribution of frogs in the province and trends in specific areas. Useful resources like recorded frog and toad calls, species fact sheets, and regional species lists are provided on the website and no training is required. There is some lack of clarity about how to enter information, however, with the forms directing contributors to a dead link on the web, while the website itself points to the generic BC Wildlife Sighting Form.

Volunteers

Rating: 2. Efforts are being made to recruit volunteers, but little is being done to retain them. Lack of clarity around how to contribute data to the project, and the difficulty (due to limited browser support) or impossibility (as the site does not appear to receive regular updates) of viewing contributed records on the web mapping application may turn potential or existing contributors away. An inactive Facebook page is also a red-flag for web-savvy potential volunteers. 15 frog and toad records were contributed through the Wildlife Species Inventory site in 2012 (Demarchi 2013)[9] – these may or may not have been entered by FrogWatch participants, however.

Data management

Rating: 2. Starting with the confusion around data entry noted above, and continuing through to semi-maintained web mapping applications, data management in this project needs improvement. There is also no indication on the site that the data is actually being used for any scientific or management purpose. Data downloads are also not supported.

Communications

Rating: 1. An inactive Facebook page, no updates on project progress on the site (including no indication that the contributed data is being put to use), and semi-functional web mapping all adds up to poor communications. Finally, there is also some confusion between this project and the national FrogWatch project.

4.12. E-Flora / E-Fauna

URL http://www.geog.ubc.ca/biodiversity/eflora/, http://www.geog.ubc.ca/biodiversity/efauna (accessed 7 April 2013)

E-Flora and E-Fauna are electronic atlases of the flora and wildlife of BC. I am including them both in a single review since the two projects are lead by the same team, use the same methods, and share a similar look and feel on the web. E-flora provides information, including reports, interactive maps, and photos, about vascular plants, slime molds, bryophytes and lichens (../efloraintroductionpage.html) while E-fauna features mammals, birds, reptiles, amphibians, insects, spiders, and some marine and freshwater animals (../introduction.html). Both include only "vouchered" data, primarily from authoritative sources such as the Royal BC Museum, BC Conservation Data Centre, UBC, University of Alaska, the Global Biodiversity Information Facility (GBIF), and the National Herbarium of Canada (see ../data.html for a complete list of E-Flora datasets and ../E-FaunaBCsupporters.html for a listing of many expert contributions to E-

[9] The BC Wildlife Species Inventory Wildlife Sighting Form is primarily used to report incidental species observations that occur during surveys for other species (e.g. a barred owl sighting during a western screech-owl survey). There were 3509 records submitted in 2012, all but 61 of which were incidental observations reported as part of a survey: 15 of these 61 were for frog species. It is not possible to tell if these were contributed by BC FrogWatch participants (*ibid.*). As the Wildlife Sighting Form is not designed for citizen science or formally linked to other specific citizen science projects it is not reviewed here.

Fauna), but also including confirmed photo records contributed by citizen scientists. Both projects rely on species specialists who volunteer their time to the project by providing species accounts and other materials and by assisting with screening contributed photos (and thereby "vouchering" them).

4.12.1. Project Management

Brian Klinkenberg is the Editor and Project Coordinator for both E-Flora and E-Fauna. Both have Advisory Committees with representation largely from science professionals (affiliations are not shown on the sites: see ../efloraacknowledgements.html and ../E-FaunaBCsupporters.html).

4.11.2. Protocol

The citizen science component for both projects consists of contributed photos accompanied by location information . E-flora requests "significant" photo records in particular: these are photos "that document range changes and fill in gaps in species distributions" (../CitizenSciencePhotoMapping.html) while E-fauna appears to be less discerning at present (../E-FaunaCitizenSciencePhotoMapping.html). As the photos will be used to identify species, both sites provide some information about what contributors should try and capture within the frame: in some cases, such as insects, a set of photos, each focussing on a different aspect of the specimen (like its legs, eyes, top or underside). Both sites also provide instructions for determining "precise" coordinates (either UTM eastings and northings or latitude and longitude), although the number of decimal places required is not defined (which could be important for ensuring precision, especially in the case of decimal degrees).

4.11.3. Volunteers

Judging from the lists of experts that contribute to the two projects, many people have been directly recruited by the project management team for their biological expertise. Others are recruited through the project website. It is unclear if all participants are truly volunteers, since many are professionals whose contributions could be better described as in-kind if the contributions are made during their usual work hours (e.g., they are paid by another academic institution or government agency during the time they work for E-Flora or E-Fauna). Many photos have been contributed to the project, including over 22,000 to E-Flora and over 14,000 to E-Fauna. 4,500 of the E-Flora photos and 3,000 of the E-Fauna have been mapped (Klinkenberg

2013c). The top ten photographers are recognized in an annual newsletter that is prepared by another volunteer.

4.11.4. Data Management and Analysis

Data is managed at the Lab for Advanced Spatial Analysis in the Department of Geography at UBC. Registered users can upload photos, which, once vetted by experts (and thereby "vouchered"), may be mapped. Contributed photos have improved understanding of species ranges (range expansions) and to documentation of previously unreported species, including at least one vascular plant. New fungi and fauna species are indicated on other photos, but confirmation is not possible from photos alone in these cases (*ibid.*). Both projects feature query tools and web mapping interfaces that display all species records from all available data sources, including mapped photos. Both project sites link to provincial, national and international sites for further information on individual species. Data agreements are in place for many of the datasets on the site that restrict sharing; however, the mapped photos could be more widely shared.

4.11.5. Communications

The websites are the primary means of communications for these two projects; a third, linked website called the Biodiversity of BC provides some overall conservation and research context to these two projects (http://www.geog.ubc.ca/biodiversity/ accessed 7 April 2013). An annual newsletter is also produced. Klinkenberg also runs a blog at http://biodiversitybc.blogspot.ca/ (accessed 7 April 2013) that provides details about updates to, or new content on, the two projects. The latest blog post was from 2 April 2013 when I visited.

4.11.6. Current Status

Both projects are active, with recent updates on both described on Klinkenberg's blog. These projects are widely used references (for instance, in the University of Victoria's library (http://libguides.uvic.ca/content.php?pid=64674&sid=2924012) and Restoration of Natural Systems Program Resources page (http://web2.uvcs.uvic.ca/courses/rns/resources/) both accessed 7 April 2013) and are recommended by organizations in BC such as BC Ministry of Environment (http://www.env.gov.bc.ca/wld/links.htm accessed 7 April 2013), the Columbia Mountains Institute of Applied Ecology (http://www.cmiae.org/Links/ accessed 7 April 2013) and the Federation of BC Naturalists (http://www.bcnature.ca/links/ accessed 7 April 2013).

The sites are also linked to the BC Conservation Data Centre's BC Species and Ecosystem Explorer (http://www.env.gov.bc.ca/atrisk/toolintro.html accessed 7 April 2013).

Overall qualitative rating (1 poor to 5 excellent):

Project Management

Rating: 5. Both sites host large volumes of data, provide extensive links to other important projects, and remain current.

Protocol

Rating: 4. Due to the wide taxonomic scope of the projects, the fact that only carefully vetted and, in the case of E-Fauna, "significant" photos are mapped, and no attempt to capture volunteer effort, the data can only be used to evaluate species ranges, and not relative abundance. Sub-projects, such as the mapping of invasive species, may provide an opportunity for collecting larger quantities of data on a much reduced set of species, enabling mapping of relative abundance and how it changes over time.

Volunteers

Rating: 4. Tens of thousands of photos have been contributed, and thousands have been accepted onto the maps, indicating an active and competent volunteer base. More could be done to retain volunteers, for instance, the annual newsletters could be linked to the site as well as sent directly, and new contributions could be described on the sites as well as on the associated blog.

Data management

Rating: 4. The large amounts of data stored on the site is all available for online review through the very detailed species pages and interactive maps. Other data sources are linked to the site, with the goal of creating a centralized reference for BC flora and fauna.

Communications

Rating: 4. The websites provide a vast amount of information through interfaces that are straightforward to navigate. More content could be provided for the volunteers on the sites, including the annual newsletter. I was unable to find any references to these projects through web searches of the literature using the keywords "E-Fauna" and "E-Flora" separately in Geobase and Web of Science databases. The links to these projects on NGO and government agency web sites suggests that the projects are widely used by resource managers, however:

many resource management professionals are contributors to the projects as well (e.g. Aaron Baldwin, Vicky Baker). There is no data available for download.

4.13. Summary of BC Conservation Citizen Science Projects

The first question posed at the beginning of the chapter was whether or not the best practices model was appropriate for use in BC, and, after completing the reviews for twelve projects using this model, I find that it can be usefully applied here. All twelve projects were evaluated against the same best practices model, creating standardized reviews. These standardized reviews in turn support comparisons between projects, including both ranking overall scores and more qualitative synopses of project characteristics within the five best practices categories. This also allows me to contrast the mean values between paired groups of projects. The paired groups I chose to contrast (and why) were: i) bird projects versus others (because bird projects were heavily used to define best practices); ii) government-run versus others (to evaluate relative resilience to changes over time); and iii) high impact management projects versus others (to compare mean scores of projects which have influenced decisions with those that have not). As bird projects have had a high science impact, i) above also provides a contrast between high science impact projects versus others.

These comparisons are summarized in the four tables below. Ratings for each project are tabulated and ranked by overall score in table 5. Tables 6 and 7 look behind the numbers: table 6 summarizes project management type and protocol methods, data accessibility through web maps and downloads, and project impact on science and management, while table 7 summarizes

Table 5. Project ratings and overall score

Project	Project Management	Protocol	Volunteers	Data Management	Communications	Total
Christmas Bird Count	5	5	5	5	5	25
eBird	5	5	5	5	5	25
BC Breeding Bird Atlas	5	5	5	5	4	24
Breeding Bird Survey	5	4	5	5	4	23
Wild Whales	5	5	5	4	4	23
E-Flora/E-Fauna	5	4	4	4	4	21
BC Butterfly Atlas	5	4	3	4	4	20
Community Mapping Network	4	4	4	3	3	18
Pacific Streamkeepers	4	4	4	3	2	17
NatureWatch	3	4	3	3	2	15
BC Shorekeepers	2	4	2	2	2	12
BC FrogWatch	2	3	2	2	1	10

volunteer recruitment and retention, communication methods and audience, and project status.

Table 6. Project management, data accessibility, and impact

Project	Project Management	Protocol	Web Maps	Download Data	Impact Science	Impact Management
Christmas Bird Count	NGO, Academia	Area sample	Yes	Yes	High	High
Breeding Bird Survey	Gov, NGO	Line, point sample	Yes	Yes	High	High
BC Breeding Bird Atlas	NGO, Gov, Private	Grid, point sample	Yes	Yes	In progress	In progress
eBird	NGO, Academia	Ad-hoc, formal	Yes	Yes	High	High
Wild Whales	Gov, Private	Ad-hoc, log book	No	No	Low	High
BC Butterfly Atlas	Private	Ad-hoc, long-term	Yes	No	None	None
BC Shorekeepers	Gov	Tidal survey	Basic	No	None	Low
Pacific Streamkeepers	NGO, Gov	Stream survey	No	No	Low	High
Community Mapping Network	Gov, NGO	Various	Yes	No	Low	High
NatureWatch	Gov	Ad-hoc	Yes	Yes	Low	Low
BC FrogWatch	Gov, NGO, Academia	Ad-hoc, long-term	Basic	No	Low	Some
E-Flora/E-Fauna	Academia	Photos	Yes	No	Low	High

Table 7. Volunteers, communications and project status

Project	Volunteers Recruitment	Volunteers Retention	Communications Methods	Communications Audience	Status
Christmas Bird Count	High	High	Web, Print, Present	Birders, General Public	Very Active
Breeding Bird Survey	High	High	Web, Print, Present	Birders, General Public	Very Active
BC Breeding Bird Atlas	High	High	Web, Print, Present	Birders, General Public	Very Active
eBird	High	High	Web, Print, Present	Birders, General Public	Very Active
Wild Whales	High	High	Web, Print, Present	Mariners, General Public	Very Active
BC Butterfly Atlas	Med	N/A	Web	Naturalists	Active
BC Shorekeepers	Low	Unknown	Nothing recent	Community-based stewards	Inactive
Pacific Streamkeepers	High	High	Web, Print, Present	Community-based stewards	Very Active
Community Mapping Network	High	High	Web, Print, Present	Community-based stewards	Very Active
NatureWatch	Med	Unknown	Nothing recent	Naturalists	Inactive
BC FrogWatch	Med	Unknown	Web, Print, Present	Naturalists	Active
E-Flora/E-Fauna	High	High	Web	Professionals, Naturalists	Active

The second question was whether projects that closely align with the best practices model are relatively more successful than others in regards to their contribution to conservation biology. Here the answer is not so equivocal. The three of the four bird projects, which were the top four ranked projects based on ratings, have had relatively high impact on science and management, and the fourth (the BCBBA) is expected to have a high impact once the results are published in 2014. There was also a relation between high scores and management impact, with the exception of the BC Butterfly Atlas, which has only been in operation for a year or so. With the exception of the three longer running bird projects, I was not able to find any indication that the other projects have had a significant scientific impact, however: even the Wild Whales project, which was tied for 4th in terms of total score, has not resulted in many, if any, peer-reviewed publications. The best practices model suggests one reason for this: of the highly ranked projects, only the bird projects make their data widely available for download. This practice opens up the data to the entire research community, not just the project managers and their partners (who may not be interested in, or have the time or capacity for, publishing), and, as new methods for data mining and data analysis are developed, provides opportunities for more publications and thus more contributions to conservation science.

Table 8. Paired-group comparisons

Project Group	Mean	Minimum	Maximum	Count	Standard Deviation
Bird	24.25	23	25	4	0.96
Non-bird	17.00	10	23	8	4.47
Gov.-run	12.33	10	15	3	2.52
Other	21.78	17	25	9	2.95
High Mgmt. Impact	21.71	17	25	7	3.20
Low Mgmt. Impact	12.33	10	15	3	2.52

The results of the three paired-groups (bird/non-bird, government-run/non-government-run, and high management impact/less than high management impact) are provided in table 8 (above). In each case, one of the groups had a mean that was higher than the other, although in the bird/non-bird comparison ranges did overlap. In the bird/non-bird comparison, the four bird projects had a mean score of 24.25 (range 23-25, standard deviation 0.96) while the eight non-bird projects had a mean of 17.00 (range 10-23, standard deviation of 4.47). The Wild Whales project demonstrates that marine biologists can run a citizen science project that nearly matches what ornithologists have achieved; although, as noted above, the publication record for this project is far below the standard set by the bird biologists. The three government-run projects had a much lower mean (12.33; range 10-15, standard deviation 2.52) than the nine other projects (21.78; range 17-25, standard deviation 2.95), and the seven high management impact projects had a much higher mean (21.71; range 17-25, standard deviation 3.20) than did the three projects with some or low management impact (12.33; range 10-15, standard deviation 2.52) (two projects, the BCBBA and the BCBA were excluded from the latter group comparison as they have not been in existence long enough to have had an impact yet). These results are not surprising since the three government-run projects were the three lowest scoring projects in this assessment and also the three projects with the lowest management impact.

The final question was whether reviewing projects *vis-á-vis* the best practices model could lead to suggestions that would improve the conservation impact of projects. Here the method seems to have particular value. First of all, as noted above, improving data access may lead to increased contributions to science. Secondly, a project management approach that builds partnerships with naturalist societies, to increase volunteer recruitment and retention, and data management experts, to improved data quality, accessibility, and analysis, can lead to more successful projects. An interesting example here is the Butterfly Atlas, which, through partnerships with NGOs, academia, and government, has grown rapidly over the past year. On the other hand, projects where project and data management is concentrated in government (BC Shorekeepers, BC FrogWatch, and NatureWatch) have not done well. It will be interesting to see if the move from government data management to NGO data management in Streamkeepers and NatureWatch projects will lead to a resurgence of these projects. Third, projects which include effort in the protocol result in data that have improved value to researchers, since this helps standardize observer bias. Finally, implementing volunteer-focussed communications leads to more volunteer interest in, and contributions to, projects. As usual, the bird projects (especially eBird in this case) set the standard here, but Wild Whales and the BC Butterfly Atlas have also adopted this approach, as can be seen from their websites in particular, with impressive results.

This review of BC projects has demonstrated that the best practices model is valid here and useful for evaluating projects, for finding project strengths and weaknesses, and for recommending project improvements. Shortcomings for most non-bird projects were identified and suggested made for improving their scientific and management impact. In the next, and final, chapter I offer recommendations for further improvements to this best practices model, including further study and incorporation of other metrics.

Chapter 5. Discussion

The contributions of citizens to conservation science and management predate the formal conceptualization of conservation biology by over 100 years (e.g. the CBC). For a period of time in the late twentieth century, many scientists were sceptical of the value of citizen science, primarily because of the lack of formal training of the observers and the lack of rigour in the study design. Work in the 1990s and 2000s to refine protocols for data collection, develop methods for data filtering, and determine the appropriate uses of volunteered data, lead to a watershed moment in 2005 when the journal Science recognized the value of citizen science within ornithology. Since that time there has been a significant blossoming of citizen science across many fields, including conservation biology. Advances in information and communications technology (ICT), including the emergence of ubiquitous computing and powerful and widely available GPS-enabled handheld computers, as well as sociological changes such as the mainstream normalization of ICT infrastructure and user-generated content (Web 2.0), increasing involvement of the public in planning and management, and government retreat from conservation funding and management, have created an environment where citizen science continues to thrive. As the practice grows, it gathers research attention: I found several citizen science typologies in the literature, for instance.

This thesis' main contributions to the study of citizen science are the identification of best practices for citizen science in conservation biology, and the application of these practices to BC projects. After reviewing a wide range of papers and projects, I found that the key components of citizen science projects are project management, protocol development, volunteer recruitment, calibration, and retention, data management, and communications. In general, projects with which include participation from scientists, government, and non-governmental interest groups in project design and management are most likely to be sustainable over the long term, contribute to science, and include linkages to government planning and policy. For example, the partnerships in ornithology between Audubon and Bird Studies Canada (NGOs), the CLO (academia), and the USGS and CWS (government), have resulted in science-based information (such as population trends and relative abundance maps) that are very useful for evidenced-based planning. Protocols developed by scientists and tested and calibrated with volunteers are most likely to result in data that will be credible to professional scientists and resource managers. Some protocols require field-based training (BCBBA, Streamkeepers, Shorekeepers) to ensure adequate data quality, while others include an estimate of effort (eBird, BBS, CBC, Wild Whales, BCBA) to standardize observer bias. Volunteers are best recruited through existing interest group networks, such as naturalist clubs, and retained by careful and creative consideration of their needs and interests, including tools for their own data explorations, and evidence of the usefulness of the data they collect to goals they care about, including conservation. As many volunteers are recruited through websites, or primarily interact with the project through the project website, creating dynamic and interactive websites is particularly important. Projects with clean and modern design, like Wild Whales, or that include social media, like the BCBA's twitter feed, appeal to the mass audiences on the web today. Data management should reduce the steps between data collection and central data storage to reduce volunteer effort and lower transcription errors. Most of the projects I reviewed employed easy to use data entry tools on their websites as the primary means of contributing data; however, none have yet developed mobile applications. Methods of automating data filtering to identify anomalous records which may require further manual review are needed as volumes of volunteered data increase. The millions of records contributed to eBird, for instance, can not all be manually reviewed: but through tools which automate filtering, regional coordinators can check up on unexpected results, helping to ensure data quality is maintained. Sharing data as well as results increases the value of any research project to scientists and managers, and creating web-based data and information sharing portals are an important feature of any communications strategy. The Bird Studies Canada data access portal is an excellent example of how data sharing can be automated online. Communications plans need to consider both internal communications, between project managers and volunteers or between volunteers and other volunteers, and external communications between the project and the scientific community, the planning and policy agencies, and the wider public. It is not enough to take a "Field of Dreams" build-it-and-they- will-come approach: people must be told about the project, and be convinced it would be worthwhile to participate. The design philosophy behind eBird, where users' interests guided the design process, instead of being tacked on afterwards, is exemplary. All project sites should have a page that lists publications and reports that use the contributed data, as the Audubon site does.

These best practices were described in chapter three and then formalized using a likert scale (1=poor, 2=fair, 3=good, 4=very good, and 5=excellent) so that best practices (those in the 4 and 5 range) could be contrasted with good (3), fair (2), and poor (1) practices. This rating scale was then applied to twelve BC projects, to first of all see if it could actually be applied in this context, and then to see if those projects which scored well also impacted science and management. The third goal was to provide concrete suggestions for improving projects which did not score well. For me, this fit with the Society of Conservation Biology's credo that one must not only rigorously conduct science, one must also work towards on-the-ground impacts.

I found the best practices model could be applied to BC projects. There was a relation between high scores and project impact in science and management. There was also a clear relation between low scores and government-lead projects. Projects which provided downloadable data – the bird projects – scored higher as a group than other projects, and were the only projects with considerable scientific impact. This leads to two main recommendations for improvement. First of all, project management should include representation from organizations that are outside government in order to build resilience against funding cutbacks or policy priorities. Secondly, projects should facilitate data sharing to enable more researchers to put the data collected by citizens to use. Other project shortcomings included a lack of current communications in many projects (the government-run projects as well as Pacific Streamkeepers, the Community Mapping Network, and the Breeding Bird Survey), and a lack of volunteer focus in project communications, especially websites (the same list of projects plus E-Flora/E-Fauna). Projects should also consider ways of capturing citizen science effort: the ornithologists have shown that this can be used to reduce observer bias and build better relative abundance models. Currently only the bird projects and Wild Whales consider effort in their protocols.

There is much that could be done to improve this best practices model. All factors were given equal weight in the project ranking: increasing the weight of some factors which may have more significant bearing on scientific impact, such as the ability to download data, should be explored as a way to refine this method. Of course, this evaluation was subjective and was, to a degree, confounded by its close linkage to model development (some projects, like CBC, BBS and eBird were extensively used to create the model that later was used to evaluate them). A study that used more reviewers, instead of just one as in this case, would provide a more robust result. It would also be interesting to replicate the study in other jurisdictions, especially in other cultures, to see if this model is universally applicable.

The best practices model indicates that the development and implementation of citizen science projects which successfully contribute to conservation science or management is quite complex, and typically requires the participation of professional scientists in lead roles. As professional involvement can be expensive, there are a number of initiatives to reduce this barrier to project initialization and sustainability, including the development of web portals providing tools for data capture, storage, and communication. Partnering with others who already have citizen science project management or data management expertise is one solution: the BCBA has taken this approach, through partnering with eButterfly and Bird Studies Canada, for instance. Another possibility is that emerging framework or toolset websites such as iNaturalist.org, CitSci.org, and CitizenScience.org, amongst others, may provide off-the-shelf resources to individuals or groups interested in undertaking citizen science projects, thereby lowering barriers to running successful projects. Still, there are limits: synthesizing data from various projects, analyzing large amounts of data, and publishing peer-reviewed papers is likely to remain beyond the reach of the non-professional for the foreseeable future.

5.1. Recommendations for Further Study

There are many places for the researcher interested in conservation citizen science to go from here. The best practices model itself could be further refined; for instance, it is currently a qualitative model and could perhaps best practices could be quantified in some areas (for instance, recommended project management effort hours per year, project budgets per species, or data storage per species). The data management and analysis component could be expanded to include recommended statistical analysis methods and methods for synthesizing data from different sources (or taking steps to make a project's data more easily synthesized with other data). There is also a need to evaluate appropriate mobile technologies: the world of apps, tablets, and smartphones is largely unexplored in this thesis and has yet to be widely adopted by citizen science projects currently underway in BC. Surprisingly, not even eBird has its own app for mobile devices.

The ornithologists got the ball rolling with the CBC, coined the term "citizen science", and continue to lead the way through the development of new projects, new web interfaces, and new data management paradigms (e.g. “ecoinformatics”). As I’ve indicated herein by largely relying on their projects to build my best practices model, there is much that the rest of the conservation biology community can learn from these leaders in the field. In particular, I would be interested to further explore their methods for developing population trends and relative abundance models using citizen science data. Could the 10 km x 10 km grid that the BCBBA used to evaluate relative abundance across the province, and which the BCBA has adopted, also be used with other species, for instance frogs and toads or cetaceans (latter would require extending the grid offshore), or even plants? Would relative abundance results differ at all if similar sized units with natural boundaries (for instance, the Assessment Watersheds in the BC Freshwater Atlas) were used instead of these arbitrary, but mathematically convenient, squares?

The taxonomic scope of citizen science also needs to expand. Currently most of the effort is dedicated to birds, butterflies, and cetaceans in BC. One wonders if there are enough potential volunteers with interests in other species groups to support expansion, however. Or are we at a point where increasing the effort to get volunteers working on new projects, rare plants, for instance, could result in less volunteers working on existing projects, such as the successful bird ones? If all projects turn to the naturalist clubs first for volunteers, these clubs may become overwhelmed with requests. Perhaps an overarching coordination agency, or affiliation, could smooth out the effort across species. But can this actually work in the real world, where the evolution of citizen science has occurred first and foremost within separate taxonomic interest groups: would people sign up in droves for a Christmas Fungi Count, for instance? The E-Flora and E-Fauna projects demonstrate that there is professional expertise across most of the BC taxonomic spectrum, but it is unclear how diverse the volunteer expertise is in the province. These two projects also suggest that by widening the species scope to all species, the analytical scope may narrow: ensuring data quality across all species puts limits on the quantity of data that can be collected on any given species, and reduces the utility of the data to supporting range mapping only.

Data collected by citizen scientists is also biased geographically, with many more records in areas where people live, work or regularly travel. Of course, there have always been limits to the spatial, and temporal (as well as taxonomic) dimensions of professional conservation biology due to costs and research interests. Analysis of the spatial distribution of volunteered data versus human population and species distribution patterns could help to provide insight into where volunteer data collection may need to be encouraged through targeted communications or supplemented by professional data collection.

There is also much to learn about how participating in citizen science may influence citizen actions and knowledge dissemination. I found some studies that looked at this question (e.g. Peers 2007, Bonney *et al.* 2009a, Connors *et al.* 2012), and the general conclusion was that citizen participation can increase interest in the natural world, may increase scientific literacy, and can reduce the traditional distance between scientists, the general public, and policymakers, helping to speed up the transmission of results. These transformative effects vary from project and depend on factors such as contact with professionals, level of involvement, and whether the project was explicitly designed to for informal learning.

These questions aside, there is good evidence that it makes sense for citizen science to be considered when professionals set out to conduct a study of a given species. There is now considerable evidence to support the statement that volunteers can collect data of sufficient quality for use in scientifically-rigorous projects. Volunteer-collected data can be used to estimate population trends and to develop relative abundance maps. In projects with wide spatial or temporal scopes, there may be no other way to collect these data. Conservation scientists and managers can collaborate with citizens in many ways to further science, policy, and planning objectives. If professionals decide to incorporate citizen scientists in their study designs, I hope that they find my best practices model helpful. In any case, they should have some knowledge of how to provide citizens with the motivation and resources to contribute to conservation biology. The exuberance of citizen science data, including data flowing from specific projects such as eBird and more random data like geolocated photos posted to Flickr, should be monitored by the professional community as a new and growing data source. Finding new ways to mine, process, and analyse these data shows promise for greatly augmenting data collected by professionals to provide a more complete picture of the conservation status of species and ecosystems.

There are limits to what can be expected from citizen scientists, however. The design of the BCBBA project, where even remote areas must be surveyed and all surveys must be done within a five-year period, bring these limitations to the fore. Professional ornithologists were hired to travel to some remote squares, and a professional project management team was required to keep track of which squares had been visited and other logistics. In cases where volunteers could harm species by trampling nests or collecting rare plants, or be harmed by them (for instance, when observing polar bears), citizen science projects may not be appropriate. For these reasons, in my view the rise of citizen science does not mean that professionals are no longer required. Instead, it means that conservation biology professionals have new allies in their efforts to understand species and ecosystems, and their efforts in protecting them.

Finally, involving citizens in science improves the chances for new discoveries, such as the expansion of species ranges found through contributions to E-Flora. It may also help to extend a deeper understanding of ecology beyond the confines of academia into the places where it can have the most impact on conservation. Increased knowledge can inform the actions of people both as individuals, where an ethic of stewardship can be fostered, and as collectives, where demands for increased consideration of conservation science can be made of policy and management decision-makers. Conservation biology, as an activist science, requires the integration of research and action; involving more people in the process can benefit both.

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