EXAMINING NATURE CONNECTEDNESS, WELLBEING AND MOTIVATION FOR SUSTAINABLE BEHAVIOUR IN THE CONTEXT OF CITIZEN SCIENCE

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by
Michelle Harnett

Presented as part of the requirement for the award of MA Degree in Sustainable Leisure Management within the Department of Recreation and Tourism Management at Vancouver Island University

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DECLARATIONS

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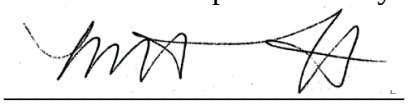

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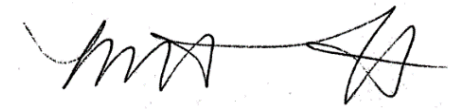

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THESIS EXAMINATION COMMITTEE SIGNATURE PAGE

The undersigned certify that they have read, and recommend to the Department of Recreation & Tourism Management for acceptance, the thesis titled *"Examining nature connectedness, wellbeing and motivation for sustainable behaviour in the context of citizen science"* submitted by *Michelle Harnett* in partial fulfilment of the requirements for the degree of Master of Arts in Sustainable Leisure Management.

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ABSTRACT

Increasing environmental degradation has intensified the need for developing effective means of influencing sustainable behaviour. Literature indicates the presence of a strong, positive relationship between nature connectedness, wellbeing and sustainable behaviour. Intervention models that promote these constructs as outcomes may more effectively influence long-term sustainable behaviour than traditional models of knowledge dissemination. This study examines the relationships between nature connectedness, wellbeing and motivation for sustainable behaviour within the context of citizen science. Citizen science engages volunteers with professional scientists in the design, data collection and interpretation of scientific studies. Using non-probability sampling techniques and a mixed methods research design, online surveys were administered via program coordinators and social media outlets to adult citizen science participants in projects around the globe. The findings suggest that citizen science exposure does positively impact upon participants' perceived levels of nature connectedness, wellbeing, and motivation for sustainable behaviour, and that deep, consistent participation in citizen science activities is key to bringing about these outcomes. Based on qualitative data, a model for the process of personal transformation that takes place within the citizen science context, including increased nature connectedness, wellbeing and motivation for sustainable behaviour, is presented. This research contributes to the broad body of literature focused on feelings of nature connectedness, wellbeing and sustainable behaviour by expanding it into the context of citizen science. It also provides a foundational study upon which to expand the knowledge base on how to effectively promote sustainable behaviour through citizen science projects and other conservation interventions, using the nature connectedness –wellbeing – sustainable behaviour framework.

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Introduction

The currently unhealthy state of the global environment is due largely to the long-term negative and cumulative effects of unsustainable human behaviour leading to the loss of biodiversity at a rate between 1,000 and 10,000 times the natural rate (WWF, 2016). Among experts, it is well recognized that many anthropogenic environmental problems are rooted in social-psychological systems and trends (Martín-López & Montes, 2015) that have led to environmental degradation due to population growth, social inequity and power imbalances, a dependency on energy from fossil fuels such as oil, coal and gas, and a value-system that supports over-consumption and economic growth over sustainable development (Fischer et al., 2012; Palomo et al., 2014). It is the latter, and specifically the behaviour of individuals underpinned by such values, that is the focus of this project.

Traditional, western-centric views of conservation and environmental protection have historically focused on the preservation of species, biodiversity and habitat, with success measured in terms of metrics such as the number of species or acres of land protected (Mace, 2014). Under this paradigm, nature is perceived to be threatened by human activity and in need of safeguarding from human transformation (Martín-López & Montes, 2015). The response has been to enact legislation and policy that manages the relationship between people and nature by creating protected areas separate from human activity, largely by restricting access to the functions that nature provides such as hunting and fishing (Palomo et al., 2014), and cultural services such as recreational activities, landscape enjoyment, and the preservation of local identities (Martín-López & Montes, 2015). This approach has exacerbated a separation of people from nature.

Rapid urbanization has also contributed to the disconnection of people from nature, as well as a reduction in the benefits that daily access to nature can provide. Cities are now home to more than half the world's population (WHO & UN Habitat, 2010), and the United Nations (2014) estimates that this will increase to 66% by the year 2050. In North America, urban dwellers presently account for more than 82% of the population with increases expected in the coming decades (United Nations, 2014). Urbanization is linked to reductions in nature appreciation and support for conservation of biological diversity (Shaw, Miller & Wescott, 2013), as well as adverse effects in resident wellbeing, such as increased risk of depression and substance abuse (Mckenzie, 2008). The move to cities has simultaneously spurred the rise of an

affluent middle class with a desire for material consumption and economic growth, at the same time as the ubiquity of communication technology has influenced the disconnection of people from daily meaningful interactions with their surroundings and each other (Folke et al., 2011), exacerbating the trend toward nature disconnection.

To alleviate negative anthropogenic effects on the environment, solutions are needed that reconnect people with the natural world, improve wellbeing and promote behaviour change toward more sustainable practices. One way this is being undertaken is by developing conservation interventions, which include any actions taken to protect, enhance, manage or restore biodiversity or the health of the ecosystem, such as legislation enactment, captive breeding initiatives, or environmental education programs (Conservation Evidence, 2016). Intervention programs have been very successful in the collection and dissemination of biological data, significantly contributing to the conservation of biodiversity and raising awareness of environmental issues. However, with conservation interventions typically designed and delivered by experts from the natural sciences such as ecology and biology, focus has been on the sharing of findings from scientific research to enhance sustainability, leaving the socially and psychologically embedded causes of unsustainable behaviour overlooked (Martín-López & Montes, 2015).

Conservation intervention strategies in North America have been used to raise public awareness of environmental issues and promote sustainable behaviour with little to no success (Saylan & Blumstein, 2011). Effective intervention strategies have been lacking largely due to insufficient understanding and integration of the social factors that affect sustainable behaviour change on the part of those delivering them, mainly natural scientists. Previous intervention models have focused on filling an information deficit, with the assumption that by increasing public awareness and understanding of environmental issues through the provision of information, people would respond by adopting more sustainable behaviours (Boyes & Stanisstreet, 2012). Some studies support this assumption, however, the relationship between information provision and behaviour change is weak and inconsistent (Ajzen, Joyce, Sheikh, & Cote, 2011; Boyes & Stanisstreet, 2012).

Extensive social-psychological research into the antecedent factors that predict and drive sustainable behaviour has revealed several key correlates. Nature connectedness (Geng, Xu, Ye, Zhou & Zhou, 2015), happiness (Corral-Verdugo, Mireles-Acosta, Tapia-Fonllem & Fraijo-Sing,

2011), intrinsic motivation (De Young, 1996), satisfaction and personal wellbeing (Kasser, 2009; Iwata, 2001) have all been implicated as determinants of sustainable behaviour. Given the considerable breadth of research into the social aspects of environmental problems, and the well-supported relationships between sustainable behaviour, nature connectedness and wellbeing, social scientists have uncovered new avenues for affecting positive social and environmental change. Unfortunately, conservation intervention design and delivery is still at the hands of natural sciences experts who struggle to integrate this information into the intervention model in meaningful and effective ways, while social and psychological systems and trends persist in disconnecting people from the natural world and environmental degradation escalates (Martín-López & Montes, 2015).

Strategies that bring people into closer connection with nature and improve wellbeing could help alleviate the negative social-psychological and environmental impacts of nature disconnection and unsustainable behaviour. As pressure mounts to ease the negative impacts of unsustainable human behaviour on the environment, and funding for conservation initiatives becomes increasingly difficult to source, it is both timely and important to examine if and how current methods are connecting people with nature, and to improve the efficacy and cost-efficiency of intervention models. While a great deal of research has been devoted to classifying and modelling the antecedents of sustainable behaviour and the mechanisms for manipulating these to achieve sustainable behaviour change, undertaking a causal or experimental study on conservation interventions is beyond the scope of this study. Rather, this research is a correlational enquiry into the perceived impacts of exposure to one type of conservation intervention – citizen science.

This study is an examination of the relationships between feelings of nature connectedness, wellbeing, and motivation for sustainable behaviour in the context of citizen science. Citizen science is a unique education and intervention model wherein volunteer participants, together with professional scientists, engage first-hand in the design, data collection and interpretation of scientific studies that contribute to knowledge and, in many cases, inform policies and initiatives. Citizen science projects range widely in scale of time and geography, as well as subject matter and activities involved. For example, volunteers may participate in a local, one-day beach clean-up initiative with a few hundred of their neighbouring residents, collecting, weighing and reporting on the types of debris collected; they may also upload the time and

location of a particular bird species to an online database, along with hundreds of thousands of other people around the world, to help scientists track behavioural changes over large periods of time and distance. Contrary to many school or government-based programs, participation in citizen science may prove particularly conducive to influencing sustainable behaviour by connecting people with nature and improving wellbeing because: 1) it takes place in the context of the natural world; 2) it is widely accessible to all demographics, is highly collaborative and usually requires no special skills; 3) participation is free and voluntary; 4) it attracts a broad diversity of participants; 5) it significantly contributes to scientific research and expands environmental knowledge; and 6) it is a rapidly expanding field, with over 500 English-language interventions related to biodiversity studies alone (Kobori et al., 2016). It is recognized that not all citizen science projects aim to influence sustainable behaviour, nor do they all identify as conservation interventions; however, these traits make citizen science a constructive model for this study. In addition, data focused on the effects that citizen science involvement may have on participants is scant, and scholars have called for more exploratory studies into the social aspects of citizen science interventions (Kobori et al., 2016). It is also recognized that, because of the voluntary and participatory nature of citizen science activities, citizen scientists are likely to possess higher degrees of nature connectedness, wellbeing and motivation for sustainable behaviour than the general population, hence their interest in participating. Therefore, this study aims to not only explore the presence of these variables among citizen scientists, but to learn about the impacts of citizen science exposure on self-reported increases in each of these variables.

Study Objectives:

1) To examine the relationships between nature connectedness, wellbeing and motivation for sustainable behaviour in the context of citizen science;
2) To identify which project typologies and traits, if any, correlate with higher self-reported levels of nature connectedness, wellbeing and motivation for sustainable behaviour as a result of citizen science participation;
3) To extract lessons learned for developing citizen science projects that can deepen nature connectedness, improve wellbeing and increase motivation for sustainable behaviour.

Literature Review

As environmental degradation due to human impact escalates, research into the factors that affect sustainable attitudes and behaviours garners increased attention. For practitioners who develop programs and initiatives that aim to transform environmentally harmful behaviours into sustainable ones, as is the case with many citizen science projects, the findings from this type of research are particularly valuable. For the purposes of this study, the following constructs are reviewed: citizen science, sustainable behavior, connectedness to nature, and wellbeing.

Citizen Science

The term citizen science was coined by the Cornell Lab of Ornithology in the mid-nineties, who broadly defines it as "research in which members of the public engage in the process of scientific investigations: asking questions, collecting data, and/or interpreting results" (Cornell University, 2016a). Also known as community science (Bear, 2016; Carr, 2004), public participation in community research (Theobald et al., 2015), and community-based monitoring (Conrad & Hilchey, 2011), the first publicly open citizen science project dates back to 1900 when the National Audubon Society recruited citizen volunteers to monitor, track and record bird migration patterns (National Geographic Society, 2016). Since then, the use of citizen science has increased dramatically, and today an enormous body of literature exists on the subject, along with institutions (Chandler et al., 2012), symposiums (Aquarium of the Pacific, 2016), publications, tools and resources all dedicated to its study and development. Due in large part to widespread internet accessibility and ease of reporting, citizen science has successfully engaged millions of citizens in scientific research on numerous science-related topics as diverse as astronomy, archaeology, and wildlife, and on scales at the community, national and global levels (Havens & Henderson, 2013).

Citizen science and the environment. Citizen science has made significant contributions to environment related studies such as ecology, climatology and biogeography. Because these disciplines require the investigation of large-scale processes over space and time, the cooperation of a widely-dispersed group of volunteer, amateur scientists allowing for unprecedented levels of free data collection at tremendous scales renders citizen science an invaluable tool for conservation researchers (Dickinson et al., 2012). Indeed, this is citizen science's greatest strength. To illustrate, a 2008 bird monitoring initiative in the UK involved approximately 400,000 volunteers in 228,000 locations, and resulted in the recording of more

than six million birds, an impossible feat for professional scientists alone (Devictor, Whittaker, & Beltrame, 2010). Modern advances in technology and the explosion of environmental interest groups offering opportunities for participation have made it easy for anyone with internet access to take part in an ecological project by accessing online protocols and learning materials, collecting data, and entering information into a centralized database where results can be viewed in real time (Dickinson, Zuckerberg, & Bonter, 2010). The ability of citizen science to vastly increase research capacity in this way has been crucial to the study of human impacts on climate and the environment. With a worldwide team of citizen scientists contributing information and raising concerns about changes in their local ecosystems, researchers have been able to reveal and track patterns of climate change across expansive geographic and temporal ranges using enormous datasets, such as changes in the migratory patterns of birds (Hurlbert & Liang, 2012) and butterflies (Howard & Davis, 2015), the movement of plant species from southern to northern regions of North America (Crall et al., 2015), and decreases in biodiversity (Goffredo et al., 2010).

Strengths of citizen science. Although it began as a way for scientists to expand their capacity to collect data, citizen science has evolved to become multipurpose, in that many initiatives are now designed to also engage participants in experiential learning and environmental education in an effort to address the social and behavioural aspects of climate change (Schwartz, 2006). As a conservation intervention, citizen science has a lot to offer. First, citizen science activities aimed at promoting pro-environmental behaviours typically take place in the context of local ecosystems and attract the participation of local residents, potentially increasing participants' sense of connection to place, nature, and science (Bonney & Dickinson, 2012), all strong indicators of successful conservation outcomes (Barbaro & Pickett, 2015; Cooper, Larson, Dayer, Stedman & Decker, 2015; Halpenny, 2010; Meyer, 2015). By directly connecting volunteers with conservation issues in their immediate surroundings, and by involving citizens in the processes of problem identification and resolution, citizen science interventions can overcome the apathy often associated with environmental awareness campaigns, and instill in participants a sense of personal responsibility, direct impact and empowerment to create positive change (Schwartz, 2006). As Schwartz (2006, p. 1551) points out, while flagship conservation species such as elephants, pandas and polar bears are beloved worldwide, "exploiting empathy for endangered species in remote ecosystems does not engage

people in the shared personal responsibility of how the communities in which we live contribute to biodiversity loss."

Second, the contextual and collaborative nature of citizen science helps to build social capital and increase community support for local environmental efforts (Schwartz, 2006). Bliss et al. (2001) affirm that citizen science activities build social capital and pro-environmental support by promoting volunteerism and cooperation, increasing community awareness of social-ecological problems, creating and strengthening connections to environment-related agencies, building leadership skills, and identifying local resources. This can increase the environmental literacy of a community, and create an ethic of environmental stewardship (Cooper, Dickinson, Phillips, & Bonney, 2007). Furthermore, collaboration between agencies and volunteers on community conservation issues is associated with increased citizen engagement in environmental management and policy decisions, the integration of indigenous and local knowledge with scientific knowledge, and increased effort toward sustainable community development (Pollock & Whitelaw, 2005).

Finally, citizen science is an affordable and widely available leisure activity that makes science and scientific inquiry accessible to the masses. Often referred to as the democratization of science (Bonney, Phillips, Ballard, & Enck, 2016; Kullenberg & Kasperowski, 2016; Hunter, Alabri, & Ingen, 2013), citizen science interventions have helped to remove barriers between private citizens, professionals and governments, and shift the power of managing complex environmental challenges rooted in social systems to anyone interested in participating. As Martín-López and Montes (2015, p. 703) state, "We should acknowledge that the era of experts is over and that community-based, interactive or participatory approaches are needed in science as a way of engaging people in knowledge-construction processes and empowering people in decision-making processes." With cuts to public funding for environmental monitoring programs and a lack of confidence in the expertise of government employees (Conrad & Daoust, 2008; Yarnell & Gayton, 2003), public interest and knowledge of the negative impacts of human behaviour on the environment has spiked (Conrad and Daoust, 2008). By bringing together a diversity of stakeholders with differing values and knowledge, conservation related citizen science interventions provide communities and organizations with a cost-effective and on-going way to monitor ecosystem changes, inform decision-making processes, transcend disciplinary

and sectoral boundaries, and empower communities and individuals to influence positive environmental change (Martín-López & Montes, 2015).

Challenges and gaps of citizen science. Despite its many strengths, citizen science as a pro-conservation intervention is not without its challenges. Volunteer fatigue, data fragmentation (Sharpe & Conrad, 2006), lack of funding (Whitelaw, Vaughan, Craig, & Atkinson, 2003), and lack of integration between community groups, NGOs and governments to ensure that data collected and concerns raised through citizen science interventions are put to good use (Milne, Rosolen, Whitelaw, & Bennett, 2006), are some of the more common difficulties that arise. Citizen science is most challenged, however, in the areas of data collection and intervention design. In a study of 388 biodiversity related citizen science projects, Theobald et al. (2015) found that data collected from just 12% of projects had informed peer-reviewed journal articles. This points to a lack of trust among professional scientists in the ability of volunteers to perform accurate and credible reporting. While concerns around volunteer objectivity (Whitelaw et al., 2003), skill level, training deficits, and error are widespread (Silvertown, 2009; Bonter & Cooper, 2012; Bird et al., 2014) and in some cases well-founded (Dickinson et al., 2012; Gardiner et al., 2012), this same study reported that one third of the 388 projects studied contained verifiable, standardized and publicly accessible data (Theobald et al., 2015), representing a loss in potential for the impacts of these projects to be fully realized. Indeed, there is inconsistency among the results of studies that have looked at the quality of data collected by citizen scientists, with some reporting accuracy comparable to that of professional scientists (Delaney, Sperling, Adams, & Leung, 2008; Crall et al., 2015; Fuccillo, Crimmins, de Rivera, & Elder, 2015; Vermeiren, Munoz, Zimmer, & Sheaves, 2016; Finn, Udy, Baltais, Price, & Coles, 2010) and others demonstrating weaknesses in the credibility of citizen collected data (Williams, Stafford, & Goodenough, 2015; Gardiner et al., 2012; Foster-Smith & Evans, 2003). This inconsistency in data quality stems from a lack of standardized modelling for intervention design (Wiggins, Newman, Stevenson, & Crowston, 2011) and best practices for data processing and validation (Bonney et al., 2009). Although efforts to develop mechanisms for data quality and validation techniques in citizen science have been successful, the challenge remains for these methods to consistently be put into practice by the organizations and practitioners of citizen science interventions (Wiggins et al., 2011). These issues demonstrate the need for more research

to develop a standardized protocol for the design of pro-conservation interventions that employ citizen science as a delivery method.

Additionally, there is a growing consensus among scholars that citizen science projects aimed at increasing environmental awareness and promoting pro-conservation behaviour change of participants have been unsuccessful because they overlook the need for cross-disciplinary collaboration between the natural and social sciences. Typically, citizen science interventions are designed and delivered by professionals from the natural sciences (Martín-López & Montes, 2015), many of whom approach pro-conservation interventions using a knowledge-deficit model, which assumes that knowledge leads to behaviour change (Boyes & Stanisstreet, 2012). Given that many of the negative human impacts on the environment are rooted in complex social-psychological structures that support and even promote unsustainable behaviours, the knowledge-deficit model represents an oversimplification of the multidimensional nature of behaviour change, and many scholars are pushing for an integrated approach to conservation interventions that would give greater consideration to these aspects (Martín-López & Montes, 2015; Stringer, Dougill, Fraser, Hubacek, 2006; Lindenfeld, Smith, Norton, & Grecu, 2014). Bringing together professionals from diverse disciplines and combining different knowledge systems into a conservation intervention that produces pro-environmental behaviours is a challenge to say the least, and will require more study into the social aspects of sustainable behaviour to be advanced.

Sustainable Behaviour

The cornerstone of a sustainable future is human behaviour change (McKenzie-Mohr, 2008). It is widely recognized that environmental degradation is, in large part, the result of unsustainable human behaviour, and that to alleviate these effects behaviour change must occur. Sustainable behaviour is broadly defined as a set of actions intended at conserving the Earth's natural resources (Corral-Verdugo, Frías, & García, 2010). Bonnes and Bonaiuto (2002) claim that sustainable actions are deliberate and effective, resulting in the protection of the planet's socio-physical environment for both present and future generations. Examples of sustainable behaviours are those which seek to minimize the negative impacts of human behaviour on the natural and built world, including waste reduction, the minimization of energy and resource consumption, and choosing non-toxic substances (Kollmuss & Agyeman, 2002).

Understanding the mechanisms by which to effectively promote and elicit sustainable behaviour is a tremendously difficult task, complicated by a multiplicity of internal and external factors that influence a person's behavioural choices. However, this has not dissuaded numerous researchers from focusing their efforts on expanding the literature on this subject. Some of the predominant structural and theoretical barriers to sustainable behaviour and the academic findings on what motivates sustainable behaviour in the context of conservation interventions are reviewed below.

Barriers to sustainable behaviour. Ample factors may constrain action against environmental degradation. These barriers present as political or economic (structural), socio-cultural, or psychological, and many are cross-cultural (Gifford, 2011; APA, 2009; Norgaard, 2009). Several authors have provided a comprehensive theoretical overview of potential barriers to sustainable behaviour in the context of climate change mitigation, including Gifford (2011), Norgaard (2009), and van Trijp (2013). Some of the more well-researched and recognized structural and psychological barriers are reviewed here.

Structural barriers. Structural barriers are imposed by government policies, business practices, and the built environments of communities (Chawla & Cushing, 2007). These barriers may constrain sustainable action even among environmentally motivated individuals, and include features such as the availability of physical infrastructure and necessary facilities, products or product characteristics (Steg & Vlek, 2009). More specifically, the availability and quality of public transportation, recycling facilities, and natural products, as well as the costs associated with these choices affects their accessibility. These constraints can severely influence behaviour, rendering motivations ineffective in producing sustainable outcomes, eg. it is difficult to recycle plastic or glass in the absence of a recycling facility or municipal recycling program. Structural barriers are an important consideration in motivating sustainable behaviour.

Psychological barriers. Identifying the psychological barriers to sustainable behaviour is a prominent area of research among social-psychologists and psychologists, and presents some of the most challenging obstacles to improving environmental conditions. Although classification of these barriers is largely theoretical, and differs among researchers, their understanding has the potential to improve the efficacy of conservation interventions (Stern, 2011). Two of the broader and more prevailing theories are reviewed here: system justification theory and social dominance theory.

System justification theory. System justification theory proposes that individuals behave in ways that rationalize and accommodate certain aspects of the societal status quo, even at the expense of their own personal or group interests (van der Toorn & Jost, 2014). Jost, Liviatan, van der Toorn, Ledgerwood, and Mandisodza (2009) found that system justification is a goal-directed, ideologically motivated process wherein, to legitimize the current social system, individuals will self-deceive or bias information, invest great behavioural effort, and take defensive action when the system is perceived to be under threat. According to system justification theory, some individuals evaluate social systems and institutions based on innate psychological needs for security, stability, reassurance, and affiliation with others who are part of the same social system (Jost, Ledgerwood, & Hardin, 2008). Because environmental problems are rooted in social systems, changing unsustainable practices requires the admission of an unjustified or illegitimate status quo – a direct contradiction of system justification needs. Therefore, conservation campaigns that attempt to affect social change are perceived as system threats that elicit defensive action, and the more motivated one is to defend the current system, the more likely one is to deny environmental problems (Feygina, Jost, and Goldsmith, 2010). Feygina et al. (2010) demonstrated that those high in system justification expressed apathy toward environmental issues and support for the perpetuation of unsustainable practices.

Social dominance theory. Variation in the belief that certain individuals naturally reap more social power and dominance describes social dominance theory (Sidanius & Pratto, 2012). Social dominance theory states that human societies organize themselves according to group-based social hierarchies in which inequality is inherent (Sidanius & Pratto, 2012). Although initially developed to describe the motivation by some individuals to legitimize and maintain social imbalances of power, social dominance theory has more recently been extended to include environmental dominance, or the belief that humans are more worthy and therefore justifiably dominate nature and other species (Milfont, Richter, Sibley, Wilson, & Fischer, 2013).

Central to this theory is social dominance-orientation, which describes the degree to which an individual supports a belief in social hierarchies organized by superior-inferior dynamics (Milfont et al., 2013). High levels of social dominance theory have been found to predict speciesism, the belief that humans dominate animals and therefore have the right to exploit them (Dhont & Hodson, 2014; Dhont, Hodson, Costello, & MacInnis, 2014), as well as

low levels of concern for the environment and disbelief in anthropogenic climate change (Milfont et al., 2013; Milfont and Duckitt, 2010).

Also associated with environmental apathy, climate change denial and unsustainable behaviour are ideologies of free-market capitalism (Gifford, 2011), Christianity (Morrison, Duncan, & Parton, 2015), and political conservatism (Zia & Todd, 2010). By improving our understanding of ideologies and social attitudes that stress hierarchical views toward nature, justify ecologically harmful behaviours, and prevent sustainable action, we can begin to seek ways to address the structural and psychological barriers that prevent sustainable behaviour (Gifford, 2011).

Motivating sustainable behaviour. The fields of sociology and psychology have given much consideration to learning how to influence behavior change, and as the urgency increases to develop more effective conservation intervention models, uncovering ways to influence behavior that is sustainable has become a major area of focus (Kirk, 2010). A number of interventions have been implemented at various levels of society and across diverse sectors, in the hopes of transforming environmentally detrimental behaviours into sustainable ones. This review discusses sustainable behaviour influence through government policy and conservation interventions.

Government policy. To address environmental challenges and meet national emissions targets, many governments implement policies that attempt to encourage sustainable behaviour and discourage unsustainable behaviour (Revell, 2013). These interventions most often take the form of environmental regulation, levies and charges for environmental misconduct, and the provision of environmental information (Lucas, Brooks, Darnton, & Jones, 2008). Considerable research suggests; however, that these top-down methods are neither effective nor viable, and they have little or no impact on behavioural outcomes (Jackson, 2005). This inefficacy is largely due to prohibitive costs of full-scale program development and enforcement, non-compliance, malpractice, and citizen push-back (Lucas et al., 2008). These methods also neglect to consider the complex and non-linear nature of environment related behaviours, which are determined by multiple antecedent factors in an endless array of diversely prioritized sequences (Revell, 2013).

A review of sustainable behaviour change models and theories, and a study on the efficacy of government initiatives aimed at promoting sustainable behaviour, argues that for environmental policies to be effective they must be consistent in their messaging, participatory

and empowering at the individual level, and holistic in that they address environmental issues at all levels of society as a whole (Lucas et al., 2008). Lavergne, Sharp, Pelletier, and Holtby (2010) found government policies that support autonomy resulted in a higher frequency of self-determined sustainable behaviours. Notably, they also found that government policies perceived to be controlling, or top-down, thwart their own efforts by demotivating sustainable behaviour to an even greater degree than autonomy-supporting policies motivate them (Lavergne et al., 2010). Therefore, for governments to successfully promote sustainable behaviour they should enact policies that support citizen autonomy, and more importantly, avoid being perceived as controlling.

Conservation interventions. Conservation interventions take on many forms and objectives. Conservation Evidence (2016), an online conservation resource and peer-reviewed journal, defines conservation interventions as, "anything you might do to manage, protect, enhance or restore biodiversity or ecosystem services", including "types of habitat or species management, methods of species or site protection, methods of controlling invasive species, species reintroduction, captive breeding, legislation, and education programmes." For the purposes of this review, the focus has been narrowed to interventions in which objectives include the promulgation of sustainable behaviours as a means to mitigate environmental degradation.

Environmental education is a significant component of interventions that promote sustainable behaviour, and these programs are often delivered by non-profit or public organizations with a mandate for environmental stewardship. Specifically, nature and environment related organizations commonly deliver public outreach programs that aim to affect sustainable behaviour by increasing environmental knowledge. The literature on the relationship between environmental education and sustainable behaviour change is inconsistent. Among others, Duerden & Witt (2010) showed that environmental education positively affects ecological attitudes and sustainable behaviour (Ajaps & McLellan, 2015; Meyer, 2015). Contrastingly, many studies suggest no strong link between environmental education and pro-environmental behaviour exists (Ajzen, Joyce, Sheikh, Cote, 2011; Boyes & Stanisstreet, 2012). Rather, research consistently supports a reliable correlation between nature connectedness and sustainable behaviour.

Nature Connectedness

Nature connectedness is defined as the degree to which a person feels a part of the natural world (Frantz & Mayer, 2014). At present, at least seven validated tools for assessing nature connectedness have been developed, all of which have been found to be highly inter-correlated upon empirical comparison (Tam, 2013). Studies using these scales to measure the relationship between nature connectedness and sustainable behaviour consistently support the presence of a strong relationship; however, it should be noted that these studies measured self-reported behaviour, which may or may not reflect actual behaviour (Lam & Cheng, 2002). By examining electricity use, an accurate measurement of actual sustainable behaviour, and comparing it with results from their own Connectedness to Nature Scale (CNS) over three separate but replicated studies, researchers found that nature connectedness was a consistently strong predictor of actual sustainable behaviour (Trostle, 2008; Frantz, Mayer, Petersen, Shammin, 2013; Frantz, Mayer, Petersen, Shammin, Bent, 2011). This supports the growing argument that nature connectedness should be an integral part of the design and assessment of conservation interventions that promote sustainable behaviour.

Research on the relationship between humans and nature is deeply embedded in human history. Since the 1970s, nature connectedness has been studied as a way to foster an ethic of environmental conservation and sustainable behaviour. Today, the literature is replete with studies in support of considerable overlap between feelings of connectedness to nature and conservation values (Arbuthnott, Sutter, & Heidt, 2014; Geng et al., 2015; Markowitz, Goldberg, Ashton, & Lee, 2012; Scannell & Gifford, 2010). Consequently, improving our understanding of how relationships between people and nature develop, how they affect personal attitudes and perceptions, and their behavioural implications, could provide a better model for conservation interventions and increase environmental care.

Theimer and Ernst (2012) state that the degree to which a person feels connected to nature is determined by a combination of the following three elements: 1) emotions and attitudes toward nature (affective dimension), 2) the degree to which nature is integrated into a person's sense of self (affective dimension), and 3) perceptions and beliefs about nature, including how much a person knows about the natural world (cognitive dimension). Zylstra, Knight, Esler and Le Grange (2014) expanded upon these three dimensions to include a fourth: actions and experiences in nature (behavioural dimension).

Emotional attitudes toward nature (affective dimension). Among studies that have been conducted on emotional attitudes toward nature and the factors that influence them, frequent interaction with nature emerges as the primary determinant of pro-nature attitudes (Theimer & Ernst, 2012). This includes frequent past exposure to a place of nature, especially one that holds special meaning and emotional connection, such as childhood experiences at a park that was regularly visited or attendance at outdoor summer camp (Barbaro & Pickett, 2015). Similarly, Cooper et al. (2015) found that place attachment is a way by which attitudes toward nature are influenced, particularly among wildlife and nature recreationists, presumably due to the frequent interactions and connections that are fostered with the natural landscapes in which these activities take place.

Various scholars have focused on different aspects of the affective dimensions of nature connectedness. Kals, Schumacher and Montada (1999) describe nature connectedness in terms of an emotional affinity toward the natural world that includes respect, love and feeling a sense of oneness with nature. Mayer and Frantz (2004) focus on trait levels of feeling in communion with nature, and others have given their attention to emotional inclinations such as sympathy and empathy for nature (Allen & Ferrand, 1999), as well as altruism toward nature (Geller, 1995). Such studies have consistently established that emotional connectivity to nature is a key indicator of environmentally protective and sustainable behaviours.

Nature integration (affective dimension). A strong link exists between the degree to which nature is integrated into a person's identity and feelings of nature connectedness (Barbaro & Pickett, 2015). Barbaro and Pickett (2015) posit that this is because people who experience feelings of personal integration with nature see themselves embedded in the natural world, as opposed to exterior to it or having dominion over it. Research by Cooper et al. (2015) showed that pro-environmental attitudes and behaviours were stronger among wildlife recreationists, such as hunters and birdwatchers, than individuals who did not participate in these types of activities. They reason that wildlife recreationists feel intimately connected to or integrated within the natural landscape, resulting in behaviours that are protective of it (Cooper et al., 2015).

Perception, beliefs and environmental knowledge (cognitive dimension). Perceptions and beliefs about the natural world affect the way individuals identify with nature, as well as how nature is defined. When Haluza-Delay (2001) asked wilderness campers to define nature,

responses included “out there”, “not at home”, “undisturbed” and “the opposite of civilization”, indicating that nature was perceived as a place removed from human activity. Even when one’s beliefs include the self as part of the natural world, environments heavily impacted by human activity, such as urban areas, can create the perception of a human-nature disconnect (Vining, Merrick, & Price, 2008).

Environmental knowledge can, in some cases, increase nature connectedness, however, research is scant and results are inconsistent, indicating the need for more focus on this relationship. One study found that only programs with “a condensed time frame of sufficient duration” affected nature connectedness positively (Ernst & Theimer, 2011, p. 592). Another showed that in some studies, participants connectedness increased, while in others it decreased or remained stable (Kossack & Bogner, 2012). In one case, prolonged connectedness was related to younger participants and higher academic levels (Liefländer, Fröhlich, Bogner, & Schultz, 2013). It should be noted that all examples found for this review examined the relationship between environmental knowledge and nature connectedness in school children, and most interventions included an experiential component, making it difficult to draw conclusions about the effects of knowledge alone.

Although existing evidence that environmental education leads to nature connectedness or sustainable behaviours is weak (Ajzen et al., 2011; Boyes & Stanisstreet, 2012), there is some evidence to indicate that the reverse relationship exists, and feelings of nature connectedness actuate increased knowledge about natural environments (Cooper et al., 2015). This contention is reasoned on the premise that people who experience feelings of closeness to nature are inclined to seek out and retain information about it (Cooper et al., 2015). Luo and Deng (2008) presented findings in support of this relationship in a study on nature-based tourism motivations, wherein the interest to learn more about nature and natural environments was found to be a motivating factor for participation in eco- or nature-based tourism activities on the part of self-described nature lovers.

Actions and experiences in nature (behavioural dimension). Experiences in nature tend to be described as outdoor recreation and sports, and nature- or eco-tourism activities that are sought for restorative or gratifying purposes, as well as field experiences that may facilitate increased understanding of nature learning (Zylstra et al., 2014). These experiences can enhance nature relationships and experiences, particularly with repeated exposure (Grimwood, Haberer,

& Legault, 2015; Schultz & Tabanico, 2007). However, Young (as cited in Zylstra et al., 2014) argues that increased connection arising from these activities is incidental due to the structured, purposefully targeted, and time/context constrained nature of these activities. According to Young (as cited in Zylstra et al., 2014), the behavioural dimensions of nature connectedness are characterized by experiences that are unstructured, creative, playful, highly sensory, and attention-focused, resulting in a stillness and presence of the mind and body. These constructs affirm the notion of nature connectedness as a complex and multi-dimensional concept determined by the synergistic interaction of one's attitudes, experiences and knowledge with respect to the natural world.

Nature connectedness and sustainable behaviour. Considerable research has revealed strong evidence in support of nature connectedness as a driver of sustainable behaviour. That is, the more closely related one feels to the natural world, the more likely one is to engage in behaviours that protect it. For example, using the Connectedness to Nature Scale developed by Mayer and Frantz (2004), Geng et al. (2015) consistently found high nature connection to be a strong determinant of sustainable behaviour. Scholars in the field of eco-psychology argue for the promotion of sustainable behaviour by fostering an increased sense of self that includes the natural world, for if we see ourselves as part of this world then destruction of it would be experienced as self-destruction (Mayer & Frantz, 2004).

Nature connectedness and wellbeing. Nature connectedness is also inextricably linked to physical, mental and spiritual health, otherwise known as wellbeing. Rigorous studies have shown the benefits of nature connectedness to be extensive and include reductions in physical disease, mortality, anxiety, depression, and blood pressure (Sandifer, Sutton-Grier, & Ward, 2015). Elevations in mood, concentration, ability to cope with life problems, and academic achievement are also correlated with nature connectedness (Sandifer et al., 2015), as are an increased sense of personal growth, autonomy and life purpose (Howell, Dopko, Passmore, & Buro, 2011).

Wellbeing

Wellbeing is a multifarious construct academically defined in terms of several theoretical perspectives (Ryan & Deci, 2001). Simply put, however, wellbeing is summarized as "optimal psychological experience and functioning," or the presence of physical, mental and spiritual health (Deci & Ryan, 2008a, p. 1). Since 1948, the World Health Organization has been defining

health as “a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity” (WHO, 2003). This is consistent with a definition posed by Ryff and Singer (2008, p. 13), who present wellbeing as “living a life rich in purpose and meaning, continued growth, and quality ties to others.” Wellbeing is concerned with the process and pursuit of self-actualization and life purpose (Disabato, Goodman, Kashdan, Short, Jarden, 2016), and includes optimal psychological functioning, as well as having meaningful pursuits (Kashdan, Biswas-Diener, & King, 2008), connections, and a holistic quality of life (Keyes & Annas, 2009; Waterman, 2008). Psychological wellbeing is widely defined in terms of living a life with meaning, realizing one’s full potential, and maintaining vital, full functionality (Ring, Höfer, McGee, Hickey, O'Boyle, 2007). Motivations, values and goals also play an important role in the achievement of overall wellbeing, along with the pursuit of realizing one’s most authentic self (Ryan, Huta & Deci, 2008). These definitions make up the three dimensions of subjective wellbeing, which include life satisfaction, having a sense of life purpose and meaning, and emotional state (i.e. happiness, sadness, anger and stress) (Steptoe, Deaton, & Stone, 2015).

Wellbeing and the environment. Literature on human wellbeing as an outcome of participation in conservation activities is prominent, and many studies report a strong positive association between the two. Koss and Kingsley (2010) researched the impact of marine conservation volunteerism on the emotional attitudes of participants. Study subjects reported gains in mental and physical health, as well as personal satisfaction and pride as a result of their contributions and the collaborative and social aspects of participation (Koss & Kingsley, 2010). Numerous studies support these findings, and provide suggestions for the mechanisms by which these physical, social and mental wellbeing outcomes are produced in the context of conservation activities. A substantial body of evidence connects exposure to nature and green spaces with improvements in health and wellbeing (Townsend, 2006; Molsher & Townsend, 2016; Richardson, Cormack, McRobert, & Underhill, 2016; Larson, Stoeckl, Farr, & Esparon, 2015). Wellness gains are also achieved through the social benefits of collaborative volunteerism in outdoor contexts, including increased social capital for the communities in which activities take place (Moore, Townsend, & Oldroyd, 2006). Where physical activity is required, conservation volunteerism has the potential to improve physical and mental wellbeing, as in the case of outdoor activities such as tree planting and restoration, invasive species removal, and species identification (Townsend, 2006; Birch, 2005). Conservation volunteerism has also been

correlated with fewer doctor's visits, an increased sense of personal security (Moore et al., 2006), gains in confidence and a sense of achievement (Yerell, 2008), and significant improvements in mood (Townsend, 2006).

Wellbeing and sustainable behaviour. Wellbeing is also implicated as a consequence of sustainable behaviour. Several studies have found associations between sustainable behaviour and psychological restoration (Kaiser, Hartig, & Bowler, 2001), intrinsic motivation (De Young, 1996), satisfaction and personal wellbeing (Kasser, 2009; Iwata, 2001), and Marks, Simms, Thompson and Abdallah (2006) demonstrated that countries practicing sustainable consumption of natural resources report higher ratings in overall life expectancy and life satisfaction. Furthermore, in a study of wellbeing correlates, Corral-Verdugo et al. (2011) showed that subjects who scored higher in psychological wellbeing reported engagement in sustainable behaviours to a greater degree than those with lower wellbeing scores. Therefore, there is evidence of a reciprocal relationship between sustainable behaviour and wellbeing.

Conclusion

A review of the literature illustrates the existence of a significant positive correlation between nature connectedness, wellbeing and motivation for sustainable behaviour. However, it also reveals the complex and multidimensional nature of sustainable behaviour change, as well as the lack of an integrated and holistic approach to influence sustainable behaviour in the current conservation intervention model. Studies that examine the social dimensions of sustainable behaviour in the context of conservation interventions have the potential to make important contributions to the development of more effective intervention methods, and expand the knowledge on how to influence sustainable behaviour by connecting people with nature and enhancing wellbeing.

Therefore, this study examines the relationships between participation in citizen science and feelings of nature connectedness, wellbeing, and motivation for sustainable behaviour in an effort to study the role of citizen science in promoting sustainable behaviours. In light of strong evidence that both nature connectedness and personal wellbeing positively influence sustainable behaviour, as well as support for personal wellbeing as an outcome of nature connectedness, a study of the associations between participation in citizen science, nature connectedness and wellbeing could provide valuable information on how to more effectively design programs that aim to promote sustainable behaviour. Given this review, I expect to find a positive correlation

between nature connectedness, wellbeing, and motivation for sustainable behaviour in the context of citizen science. The literature also implies that the more closely a project brings volunteers into contact with nature and the more nature-centric a project is, the more significant both the correlation between the variables, as well as the correlation between self-reported increases in these variables, will be.

Method

Research Design

This study used a non-experimental, mixed methods research design to examine the relationships between participation in citizen science and feelings of nature connectedness, wellbeing, and motivation for sustainable behaviour. Non-experimental methods are widely used in social research to study variation in populations as they exist, without the manipulation of variables (Veal, 2006). The use of a mixed methods approach allows for data to be triangulated as convergence is sought between qualitative and quantitative data (Creswell, 2003). This lends increased credibility to the findings as the potential biases inherent within one method are neutralized by the other (Creswell, 2003). It also allows the researcher to develop a deeper, fuller understanding of the data as one source may help to inform the other.

This study employed a survey research strategy. Surveys are commonly used in non-experimental research designs as a means of collecting the views and attitudes of a sample population within a larger population (Fowler, 2009). Previously validated scales adapted from academic literature were used to assess participants' feelings of nature connectedness, wellbeing, and motivation for sustainable behaviour. An extensive review of the literature on related topics such as attitudes toward climate change, citizen science, sustainable behaviour, nature connectedness, and wellbeing showed near exclusive use of survey methodology (Barbaro & Pickett, 2015; Cooper et al., 2015; Koss & Kingsley, 2010; Liefländer, 2015; Theimer & Ernst, 2012) further justifying the use of it in this study.

Materials

Rating scales were used to collect data on volunteers' nature connectedness, wellbeing and motivation for sustainable behaviour. Rating scales ask respondents to define the extent to which they hold an attitude or perspective on a spectrum (Babbie & Benaquisto, 2009). Socio-demographic information was collected via multiple choice questions, as were questions related to citizen science experiences and project traits. Where the number of possible responses to a question varied beyond that which could be captured by a multiple-choice format, space for text was provided for study subjects to answer in their own words. Questionnaires of this type are efficient for participants to complete and for researchers to statistically analyse (Babbie & Benaquisto, 2009).

Nature connectedness. Nature connectedness was assessed by the *6-Item Nature Relatedness Scale* (Appendix A), also known as the *NR-6*, which synonymously refers to nature connectedness as nature relatedness (Nisbet & Zelenski, 2013). The NR-6 is an abbreviated and validated version of the 21-item Nature Relatedness scale developed by Nisbet, Zelenski and Murphy (2009), which measures cognitive, affective and behavioural dimensions of individual nature relatedness. In an effort to condense the scale while maintaining its psychometric properties, the authors found that just 6-items taken from two of these dimensions, affective and experiential, performed as well as the 21-item scale in terms of measuring the underlying construct of nature relatedness (Nisbet & Zelenski, 2013). Factors assessing the affective dimension of nature relatedness reflect how strongly a person identifies with the natural world, and are represented by four items: 1) I always think about how my actions affect the environment, 2) my connection to nature and the environment is a part of my spirituality, 3) my relationship to nature is an important part of who I am, and 4) I feel very connected to all living things and the earth. Two of the six items capture the experiential dimension, defined as a person's level of familiarity and attraction to nature: 5) my ideal vacation spot would be a remote, wilderness area, and 6) I take notice of wildlife wherever I am. Respondents were asked to rate the extent to which they agree with these six statements on a 5-point Likert scale ranging from one (disagree strongly) to five (agree strongly). The NR-6 was chosen over a multitude of other scales available on this topic because of its convenient length and superior performance. In a study of the reliability and predictive validity of the NR-6, Nisbet and Zelenski (2013) statistically confirmed the scale's stability, consistency and truthfulness.

Personal wellbeing. Personal wellbeing was assessed using the *Personal WellBeing Index – Adult Version (PWI-A)* (Appendix B). This scale was developed by the International WellBeing Group, a consortium of researchers from more than 50 countries who have partnered to develop the PWI-A into a valid instrument that can be used cross-culturally (International Wellbeing Group, 2013). This scale, in its 5th edition, has been translated into more than 25 languages and used in various leisure related studies to measure wellbeing. Comprised of 8-items related to various life domains, the scale asks respondents to rate their satisfaction with each domain on a scale of zero (no satisfaction at all) to ten (completely satisfied). These domains are standard of living, health, life achievement, personal relationships, feelings of safety, feeling part of community, security, and religion/spirituality. Each domain can then be analysed separately,

or an average of the scores can be calculated to produce a measure of overall subjective wellbeing. The PWI-A has undergone rigorous testing and is deemed a valid and reliable scale (International Wellbeing Group, 2013).

Sustainable behaviour. Sustainable behaviour was assessed by *The Motivation for Environmental Action Scale* (Appendix C). This scale was developed and provided, with permission, by The Cornell Lab of Ornithology, who has played an integral role in developing the field of citizen science since 1966 (Cornell University, 2016b). The title of this scale is a surrogate for the operationalisation of sustainable behaviour in the current study, and is referred to as motivation for sustainable behaviour in subsequent sections. This scale consists of 14-items on a 5-point Likert scale ranging from one (strongly disagree) to five (strongly agree). Seven of the items measure internal motivation for positive environmental action, and seven items measure external motivations for positive environmental action. To behave in a sustainable way for personal psychological gain or because it aligns with one's values or beliefs are examples of internally motivated actions. Externally motivated actions include those which are performed to avoid judgment from others or for fear of negative consequences. Research suggests the more internally motivated an action is, the more it will be self-endorsed and persist (Deci & Ryan, 2008b). Internally motivated actions are also associated with psychological wellbeing (Deci & Ryan, 2008b). Within this scale, respondents were asked to think about some of the things they do to protect nature or help solve environmental problems, and why they do these things. By subtracting the average external motivation score from the average internal motivation score, an overall motivation score was created for each study participant. This scale was specifically designed for measuring the outcomes of citizen science programs and volunteer attitudes as part of the Lab's DEVISE project (Developing, Validating, and Implementing Situated Evaluation Instruments) (Cornell University, 2016c). The Motivation for Environmental Action Scale has undergone rigorous validity and reliability testing by the Cornell Lab of Ornithology, and was used to measure participant's internal and external motivations for engaging in sustainable behaviours.

In addition to these three scales, respondents were asked 10 descriptive questions related to their citizen science activities. These were: 1) have you been involved in more than one citizen science project, 2) are you actively involved in a citizen science project at the moment, 3) how long have you been/were you involved in this project, 4) what kind of citizen science project

is/was it, 5) name of the project, 6) name of the organization that provides the project, 7) name of the person who manages the project, 8) roughly how many hours per week do/did you participate in the project, 9) what type of activities are/were you involved in when you are/were participating, and 10) please describe what you do in your citizen science project. Survey branching was used to bifurcate present and past tense questions depending on whether or not citizen scientists reported being presently or formerly active in a citizen science project. One additional citizen science question was asked of formerly active citizen scientists: how long has it been since you were involved in your last citizen science project.

Where the number of possible responses to a question varied beyond that which could be captured by the multiple-choice format, space for text was provided for study subjects to answer in their own words. Open-ended questions of this nature included: *what kind of citizen science project is/was it*; *name of the project*; *name of the organization that provides the project; name of the person who manages the project*; *roughly how many hours per week do/did you participate*; *what types of activities are/were you involved in when participating*; and *please describe what you do/did in your citizen science project*.

Six additional questions asked citizen science participants to assess the impact that citizen science involvement has had on their personal wellbeing, nature connectedness and motivation for sustainable behaviour, both quantitatively and qualitatively. A rating scale ranging from one to five was provided for each variable in which one represented “not at all” (no impact) and five represented “very much so” (strong impact). Respondents were then asked to qualify their responses in their own words by describing what it was about citizen science that had made them feel that way.

Finally, three demographic questions asked about gender, age range, and country of residence. The questionnaire was created in Google Forms, a free web-based survey administration tool that allows response data to be downloaded to survey analysis software (Appendix D).

Sampling Strategy

A non-probability sampling strategy was used to determine the sampling frame. Non-probability sampling is an appropriate and useful sampling strategy when random sampling is not feasible. The process of finding citizen scientists began with contacting several online databases, including Scistarter.com, Zooniverse.org, CitizenScienceCenter.com,

CitizenScientists.ca, and NatureCanada.ca. These sites, and others like them, were asked for their assistance in sharing the online survey with citizen science project coordinators and citizen scientists. A website was created so that project and database managers could access more information about the study, and feel confident and informed of what they were being asked for help with. The website contained detailed information about the study, the researcher, the literature review, the questionnaire, and ways to help, including how to share the questionnaire link via email, Facebook, and Twitter. Draft emails, as well as Facebook and Twitter posts that included the questionnaire link were provided to make it as easy as possible to solicit the help of coordinators. This website was shared only with managers of citizen science projects and databases, and was not shared with potential survey respondents so as not to bias responses. Managers were asked not to share the information contained within the site with citizen scientists. Other projects and coordinators were identified and contacted directly via an online search.

Social media was also used to recruit citizen scientists directly. Facebook and Twitter accounts were created specifically for the study, where the questionnaire link and study information were posted. These accounts also allowed for a two-way exchange of information between the researcher and the sample population, and was at times a helpful means by which to communicate with citizen scientists, address any issues or concerns expressed, lend credibility to the study, and increase recruitment rate. A search of “citizen science” on Facebook and Twitter identified several groups and organizations where citizen scientists from various projects were sharing information. Daily postings to these groups from the study’s social media accounts and on the study Facebook and Twitter pages themselves, provided information about the study as well as the questionnaire link, and asked for the participation of citizen scientists. A majority of study participants were recruited in this way. Bitly (2017), a link management platform, was used to shorten the questionnaire link for aesthetic appeal and functionality via social media.

This type of sampling strategy led to snowball sampling, as coordinators of citizen science databases and projects became followers of the study’s social media sites and began to recruit other coordinators and citizen scientists by “re-posting” and “re-tweeting” these posts. Citizen scientists also shared the link with others in their networks. Snowball sampling is a non-probability sampling strategy that is practical in social research for accessing populations that may be difficult to access otherwise, and is an appropriate recruitment method for exploratory

studies (Research Methodology, 2016). Therefore, there were no geographical boundaries on the sample frame, which consisted of self-identified citizen science participants. All participants were provided with a participant consent form (Appendix E), which was embedded on the first page of the online questionnaire.

Data Analysis

The analysis phase was guided by three objectives: 1) to examine the relationships between nature connectedness, wellbeing and sustainable behaviour in the context of citizen science, 2) to identify citizen science project traits, if any, that correlate with self-reported increases in nature connectedness, wellbeing and sustainable behaviour, and 3) to extract lessons learned for developing citizen science projects that strengthen nature connectedness, wellbeing and sustainable behaviour. Questionnaire data were downloaded from Google Forms and stored in an Excel spreadsheet. A master was stored in its original condition on a password protected computer, and a copy was made for the analysis process.

First, the data were cleaned to remove all incomplete or invalid entries. Each industry scale came with its own set of instructions for how to clean the data they obtained. These were followed for each of their respective data sets. The remaining data were cleaned by expunging all invalid entries to yield a total number of complete and valid responses. Invalid entries included those surveys for which the same numbered multiple-choice response was provided for every question, or where insincere responses were provided for open-ended questions. There were four respondents who expressed in the open-ended questions that they did not identify as citizen scientists. These surveys were also removed from the final data set. This process yielded 384 complete and valid surveys, which were saved as a working excel file on a password protected personal computer.

Phase I analysis involved uploading all survey data into qualitative research analysis software, Nvivo 11. Here, qualitative responses underwentinductive analysis to unearth major themes and domains as part of the process to code, and in some cases quantify, the data. Each question was individually analysed by initially reading all responses, then re-reading them multiple times to identify common themes, both large and small. Smaller themes were then grouped into larger theme categories, or domains. For the qualitative questions relating to self-reported increases in each of the variables, relationships between the variables were identified by reading key responses from each of the major themes derived from each variable and making

manual notes about how these themes overlapped or interacted. Using these notes, a visual was created using PowerPoint 2016 to illustrate the interactions between the variables based on survey responses.

In order to quantify open-ended responses from multiple choice questions so that they could be quantitively analysed, the same process was carried out to identify major themes among responses. These themes would become response categories and assigned a response number in sequence with the other numbered responses of the same question, as well as a category title. In this way, new response categories were created from the open-ended responses and added to the list of possible categories for each multiple-choice question.

In Phase II analysis, quantitative data were then uploaded to Statistical Package for Social Sciences (SPSS) Version 24 to undergo statistical analyses. The unit of analysis for this study was individual citizen scientists.

Findings

As experts increasingly recognize that many root causes of anthropogenic environmental issues are embedded in social-psychological systems and trends (Martín-López & Montes, 2015), efforts to counter these impacts through conservation interventions has expanded. Many intervention models, however, still emphasize learning merely through the dissemination of knowledge and overlook the socially and psychologically embedded causes of unsustainable behaviour (Martín-López & Montes, 2015). Although increased knowledge about environmental issues is a crucial first step toward sustainable behaviour change, other elements play an important role in how people interact with and behave toward the natural world, such as nature connectedness and wellbeing. This study sought to uncover the relationships between nature connectedness, wellbeing, and sustainable behaviour in the context of citizen science – an innovative and widely available intervention model that engages public citizens with professional scientists in the design, data collection and interpretation of scientific studies. This chapter presents the findings of a two-phase analysis process. In Phase I, qualitative data were analysed to uncover major themes and domains as part of the process to code, and in some cases quantify, the data. In Phase II, quantitative data were analysed using descriptive and inferential statistics. Descriptive statistics provide an overview of the data and the parameters of a population, and are useful for highlighting patterns and trends within a population (Lund Research Ltd., 2013).

First, a descriptive overview of the study sample and citizen science experiences is provided. Deeper analysis using inferential statistics are then presented as part of an examination of the relationships between citizen science experiences and nature connectedness, wellbeing and sustainable behaviour. Finally, a qualitative analysis of open-ended survey questions on self-reported increases in nature connectedness, wellbeing and sustainable behaviour due to citizen science participation is provided.

The total number of surveys received was 408, all of which arrived through the online Google Forms survey tool during the recruitment period between November 7, 2016 and January 17, 2017. After reviewing responses for incompleteness, repetition, and invalid entries, which included those filled out disingenuously or by non-citizen scientists, the remaining sample size of usable surveys (N) was 384. This represented an adequate sample size to generalize to the citizen science population overall, according to calculations made by Calculator.net (2016) for an

unlimited population size at a 95% confidence level. However, because of the sampling strategy used, generalization of these findings cannot be inferred and these results can be said to reflect the sample population only. All statistical analyses were performed using SPSS version 24, and all qualitative analyses were performed using Nvivo 11.

Sample Demography

The sample reflected a wide diversity of citizen science participants representing all age ranges and 22 different countries. These are summarized in Table 1. A majority of respondents were female (63.5%), 45 years of age and over (61.0%), and living in the United States (49.5%) or Canada (34.6%).

Table 1

Demographic Distribution of Study Sample

		Number of Respondents (N=384)	Percent of Respondents
Gender	Female	244	63.5
	Male	140	36.5
Age Range	18-24	15	3.9
	25-34	73	19
	35-44	62	16.1
	45-54	77	20.1
	55-64	97	25.3
	65+	60	15.6
Country of Residence	United States	190	49.5
	Canada	133	34.6
	Australia	32	8.3
	United Kingdom	5	1.3
	The Netherlands	4	1.0
	Germany	3	0.8
	Mexico	2	0.5
	Other	16	4.8

Citizen Science

Surveys were comprised of 11 questions aimed at collecting information about each respondent's citizen science project and experience. Four of these questions were in multiple-choice format. The first question asked, "Have you been involved in more than one citizen science project?" to which 82.6% replied *yes* and 17.4% replied *no*.

The second question asked respondents if they were actively involved in a citizen science project at the time of taking the survey. Active citizen scientists represented 59.4% of the sample, while 40.6% were inactive. Using survey branching, inactive citizen scientists were asked an additional multiple-choice question to describe their citizen science experience: “How long has it been since you were involved in your most recent citizen science project?” Most respondents had not been active in more than nine months (16.9%), with 12.8% active within three months of completing the survey.

Finally, all citizen scientists were asked *how long they have/had been involved* in a citizen science project. More than half had been involved for longer than 9 months (59.4%), while 15.1% reported involvement of less than one week. Approximately one quarter (25.5%) of the sample were involved for a period between one week and 9 months.

In addition to exclusively multiple-choice questions about citizen science, three questions combined multiple choice responses with an “other” field, where respondents could answer in their own words. For these questions, open-ended responses were analysed and coded into major themes to produce a categorical list of responses to each question. These questions elicited information about the *kinds of projects* citizen scientists were involved in, how many *hours per week* they participated, and what *types of activities* they were involved in when participating. Nine kinds of projects were identified, with wildlife being the most highly represented (n=145). Almost half of the sample participated in citizen science projects between zero and two hours per week (49.7%), the largest proportion, and among the nine types of activities described, most respondents were involved in data collection activities (71.6%), among others. Table 2 summarizes these response categories and their frequencies.

Table 2

Citizen Science Trait Categories and Frequencies

		Number of Respondents (N=384)	Percent of Respondents
Kind of Project	Wildlife	145	37.8
	Marine	89	23.2
	Conservation	54	14.1
	Botanical/plant/forestry	28	7.3
	Astronomy	16	4.2
	Environment (General)	33	8.6

	Climate and Weather	7	1.8
	Human Health and Medicine	7	1.8
	Non-nature Related	3	3
Hours per Week	0-2	191	49.7
	3-5	90	23.4
	6-8	32	7.8
	More than 9	52	13.5
	Part of Job or Ongoing	6	1.6
	Variable or Seasonal	13	3.4
Type of Activities	Data Collection	275	71.6
	Data Entry/Reporting	200	52.1
	Monitoring/Watching/Counting	249	64.8
	Surveying	81	21.1
	Data Sorting	55	14.3
	Mapping	37	9.6
	Labour	29	7.5
	Data Analysis	10	2.6
	Support	30	7.8

Note: Bolded text indicates categories that were identified through analysis of open-ended responses.

Descriptive Results of Nature Connectedness, Wellbeing and Sustainable Behaviour

To examine the relationships between nature connectedness, wellbeing and sustainable behaviour in the context of citizen science, the survey employed established and validated scales that measured the extent to which these attributes were present in each respondent. Each scale came with its own set of instructions for cleaning the data and tabulating an overall score of that attribute for each respondent. In this way, a single value was obtained for each respondent of each composite variable. Both the nature connectedness and motivation for sustainable behaviour questionnaires employed a Likert scale that ranged from one (strongly disagree) to five (strongly agree). The wellbeing questionnaire asked respondents to rate their level of satisfaction between zero (not satisfied at all) and ten (completely satisfied) on eight quality of life domains. The results of the nature connectedness and wellbeing scales were averaged to generate a score between one and five, and zero and ten respectively, with a higher score reflecting a stronger presence of the attribute. The motivation for sustainable behaviour scale measures both internal and external motivations on a scale of one (strongly disagree) to five (strongly agree). It then subtracts the averaged external motivation score from the averaged internal motivation score to generate an overall motivation score for each respondent. Therefore, this attribute is reflected by a score that ranges from minus four to positive four, where a positive score reflects

predominantly internal motivations, and a negative score reflects predominantly external motivations.

In general, citizen scientists showed high levels of nature connectedness (*M*=4.28), wellbeing (*M*=7.5) and motivation for sustainable behaviour (*M*=1.67). The nature connectedness attribute showed the smallest amount of variability around the mean (*SD*=0.59), and none of the variables were normally distributed. These findings are summarized in Table 3.

Table 3

Nature Connectedness, Wellbeing and Sustainable Behaviour of Study Sample

	Range	N	Min.	Max.	Mean	Std. Dev.
Nature Connectedness	1 to 6	384	1.66	5.00	4.28	0.59
Wellbeing	0 to 10	384	3.11	9.88	7.50	1.22
Sustainable Behaviour	-4 to 4	384	-0.14	3.42	1.67	0.76

Relationships Between Composite Variables: Nature Connectedness, Wellbeing and Sustainable Behaviour

To examine the relationships between nature connectedness, wellbeing and motivation for sustainable behaviour in the context of citizen science, a Spearman's correlation was performed. Spearman's correlation is a non-parametric test of the strength and direction of association between at least ordinal-level variables, and is useful when the assumptions of the more powerful Pearson's correlation are violated (Rosenthal, 2001). The results of this test showed only very weak or no associations at all between the three variables, and no statistical significance at the 95% confidence level. This finding is inconsistent with multiple studies that have reported positive associations between nature connectedness, wellbeing and sustainable behaviour, and is likely due to the lack of variability among scores in the sample.

Relationships Between Self-Reported Increases in Nature Connectedness, Wellbeing and Sustainable Behaviour - Quantitative

Three survey questions asked respondents to rate, on a scale of one (not at all) to five (very much so), how much they felt their nature connectedness, wellbeing and motivation for sustainable behaviour had increased as a result of their participation in citizen science. A majority of respondents reported increases in each, with 59.4% reporting increases in all three.

More than three quarters (77.8%) of the sample reported an increase in nature connectedness with 51.0% reporting a substantial increase, or five on the Likert scale (very much so). Similarly, 76.8% of respondents reported an increase in wellbeing with 46.6% reporting a substantial increase, and 70.1% reported an increase in motivation for sustainable behaviour with 43.7% reporting a substantial increase. A summary of these findings and their overlap is presented in Figure 1.

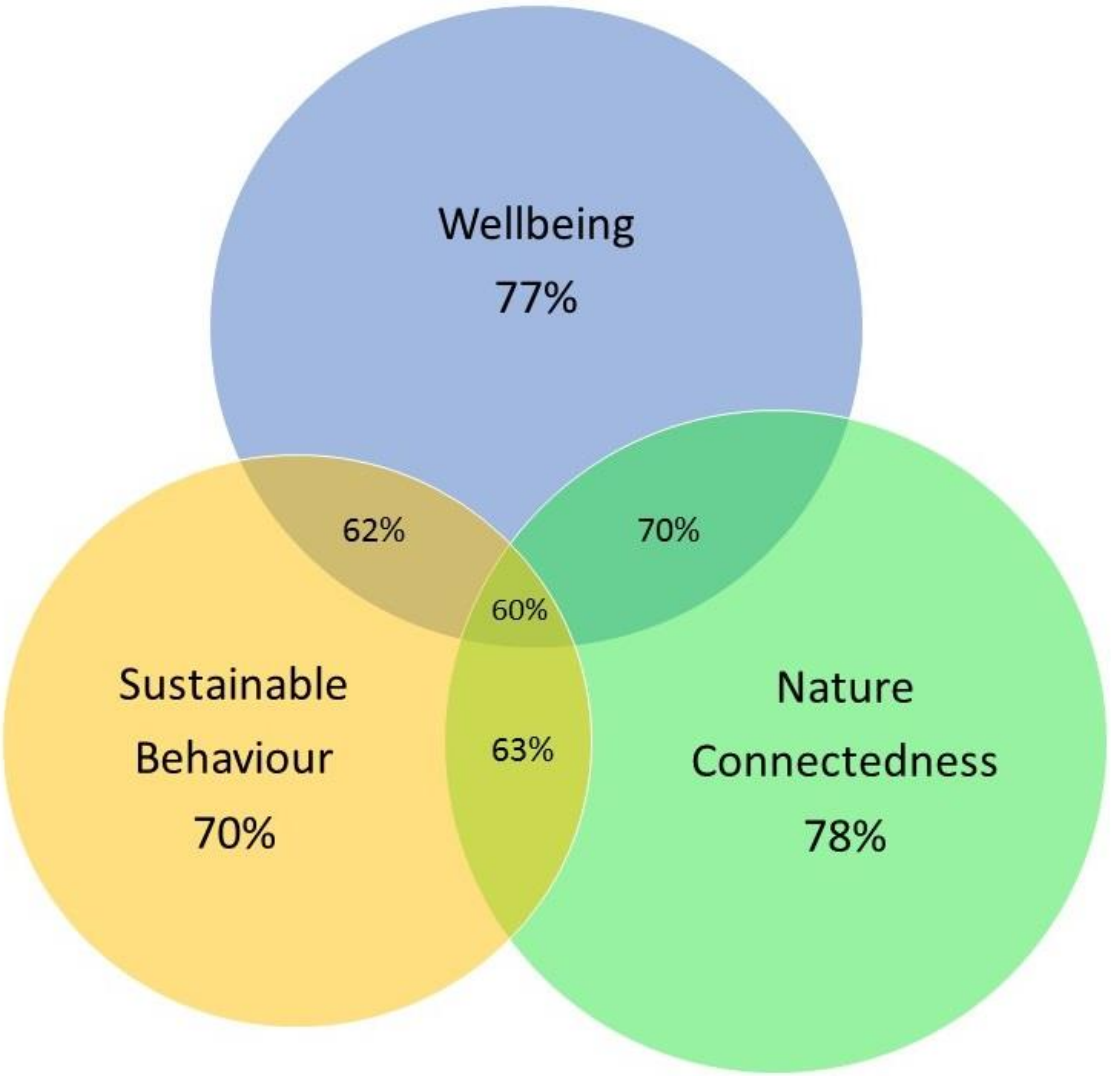

Figure 1. **Venn diagram showing the proportion of respondents who reported increases in each variable and group of variables.** Values reflect percentage of the entire sample population and have been rounded for ease of interpretation.

To explore the relationships between self-reported increases in nature connectedness, wellbeing and sustainable behaviour, a Spearman's correlation was performed for each pair of variables. A statistically significant positive correlation was present between each (Table 4).

Consistent with the descriptive analyses, this indicates that those who report an increase in one variable are likely to also report an increase in one or both of the other variables. The strongest association was expressed between nature connectedness and wellbeing, $r_s(382) = .672$, $p < .001$.

Table 4
Correlations Between Self-Reported Increases in Nature Connectedness, Wellbeing and Sustainable Behaviour

			NC	WB	SB
Spearman's rho	NC	Correlation Coefficient	1.000	**.672****	**.576****
		Sig. (2-tailed)	.	.000	.000
		N	384	384	384
	WB	Correlation Coefficient	**.672****	1.000	**.624****
		Sig. (2-tailed)	.000	.	.000
		N	384	384	384
	SB	Correlation Coefficient	**.576****	**.624****	1.000
		Sig. (2-tailed)	.000	.000	.
		N	384	384	384

Note: **Correlation is significant at the 0.01 level (2-tailed). In this and following tables, NC = nature connectedness, WB = wellbeing, and SB = sustainable behaviour.

Relationships Between Self-Reported Increases in Nature Connectedness, Wellbeing and Sustainable Behaviour and Citizen Science Project Traits

This study sought to investigate the relationships between citizen science project traits and nature connectedness, wellbeing and sustainable behaviour in an effort to identify key project traits that positively correlate with motivation for sustainable behaviour. To this end, seven questions asked respondents about different aspects of their citizen science experience, including: 1) if they had been involved in more than one citizen science project, 2) if they were presently active in a project, 3) how long they had been involved, 4) how many hours per week they participated, 5) the kind of project they were involved in, 6) the types of activities they did, and 7) a description of activities. A summary of the descriptive analyses for each of these questions was provided in the previous section on citizen science. Inferential statistical analyses were conducted to identify which project traits, if any, correlate with higher frequencies of self-reported increases in nature connectedness, wellbeing and motivation for sustainable behaviour due to citizen science participation.

Citizen science question one asked if participants had been *involved in more than one citizen science project*. An independent samples t-test was used to compare the mean scores of those who had participated in more than one project with those who had not, in all three self-report variables. Independent samples t-tests are a measure of the difference between two population means (Rosenthal, 2001). They assume relatively equal population sizes in both groups (Rosenthal, 2001). Therefore, to match the sample size of respondents who reported not being involved in more than once citizen science project (n=69), a randomized sampling of 69 responses was chosen from the overall population sample of respondents involved in more than one citizen science project (n=315) for the calculation. In all three self-report variables, the mean scores of those who had participated in more than one citizen science project were higher than the scores of those who had not (Table 5). The p-values for nature connectedness and wellbeing indicated that these differences were statistically significant. This demonstrates that people who participate in more than one citizen science project are more likely to report increases in nature connectedness, wellbeing and motivation for sustainable behaviour.

Table 5

Results of T-Test and Descriptive Statistics for Citizen Science Question One

Have you been involved in more than one citizen science project?										
	Yes			No			95% Confidence Interval	Sig. (2-tailed)	t	df
	M	SD	n	M	SD	n				
NC	4.22	.855	69	3.86	1.128	69	[.025, .700]	**.035***	2.12	126
WB	4.14	.845	69	3.65	1.270	69	[.129, .856]	**.008***	2.68	118
SB	4.04	1.049	69	3.68	1.334	69	[-.042, .767]	.079	1.77	128

Note: Bolded text indicates samples where equal variances were not assumed as a result of Levene's Test for Equality of Variances. * $p < .05$.

Citizen science question two asked participants if they were *actively involved in a citizen science project* at the time of being surveyed. The mean scores of those actively involved were higher on all three self-report variables than those not actively involved (Table 6). A statistically significant difference was found between citizen scientists who were currently active in a citizen science project versus those who were not currently active in a project on all three composite

variables. Therefore, active citizen science participants are more likely to report increases in nature connectedness, wellbeing and motivation for sustainable behaviour due to their citizen science participation.

Table 6

Results of T-Test and Descriptive Statistics for Citizen Science Question Two

Are you actively involved in a citizen science project at the moment?	Yes			No			95% Confidence Interval	Sig. (2-tailed)	t	df
	M	SD	n	M	SD	n				
NC	4.42	.825	157	3.97	1.062	157	[.235, .657]	**.000***	4.15	294
WB	4.37	.811	157	3.83	1.165	157	[.312, .758]	**.000***	4.72	278
SB	4.15	1.105	157	3.78	1.243	157	[.115, .637]	.005*	2.83	307

Note: Bolded text indicates samples where equal variances were not assumed as a result of Levene's Test for Equality of Variances. * $p < .05$.

Citizen science question three queried participants on their *length of involvement* in a citizen science project. Somers' d was run to determine the association between length of involvement in a citizen science project and self-reported increases in nature connectedness, wellbeing and motivation for sustainable behaviour among study participants. Somers'd is a non-parametric test of strength and direction of association between two ordinal-level variables, in which one variable is dependent and the other is independent (Lund Research Ltd., 2013b). It is interpreted by proportional reduction in error, and is an indication of how much we can improve our chances of being able to guess the value of the dependent variable by knowing the value of the independent variable (Somers, 1968). The results indicate a positive and statistically significant association between length of involvement and increases in all three self-reported variables: nature connectedness ($d = .143$, $p < .002$), wellbeing ($d = .140$, $p < .003$) and motivation for sustainable behaviour ($d = .106$, $p < .026$). These values show that by knowing a participants' length of involvement in citizen science projects, the chances of guessing their nature connectedness, wellbeing and motivation for sustainable behaviour improve by 14.3%, 14.0% and 10.6% respectively.

Citizen science question eight asked respondents how many *hours per week* they participate, or participated, in a citizen science project. Somers' d was run to determine the association between hours per week and self-reported increases in nature connectedness, wellbeing and motivation for sustainable behaviour among study participants. A positive and statistically significant association was found between the number of hours per week spent participating in citizen science projects and increases in all three self-reported variables: nature connectedness ($d = .129$, $p < .003$), wellbeing ($d = .172$, $p < .000$) and motivation for sustainable behaviour ($d = .111$, $p < .012$).

The results of these tests reveal a weak but statistically significant association between both length of involvement and participatory hours per week in citizen science projects, and self-reported increases in nature connectedness, wellbeing and motivation for sustainable behaviour. Respondents who reported a longer length of involvement in a citizen science project and more participatory hours per week, were more likely to also report higher levels of nature connectedness, wellbeing and motivation for sustainable behaviour due to their citizen science involvement than those who reported a shorter length of involvement and fewer participatory hours per week.

Three additional citizen science trait questions collected qualitative data, wherein respondents were provided with a response field to answer the question in their own words. Two of these questions – *kind of citizen science project* and *types of activities* involved in when participating – were multiple-choice combined with an open-ended "other" field option where survey participants could respond in their own words, since all possible responses could not be captured by multiple-choice format. The third question asked respondents to *describe what they do* when participating in citizen science activities, and was entirely open-ended with no multiple-choice options available. The open-ended responses from these three questions underwent qualitative data analysis to uncover major themes. These themes were then used to define new categories of citizen science project traits based on the data provided. After assigning each category a number, inferential statistical analyses were carried out to identify any existing associations between response categories and self-reported increases in nature connectedness, wellbeing and motivation for sustainable behaviour. These analyses and their results are described more fully in the following sections.

Kind of citizen science project. For the purposes of this study, "kind" of citizen science project was defined predominantly by the broader focus or subject matter of the project. The options provided by multiple-choice were marine (n=89), wildlife (n=145), conservation (n=54), botanical/plants/forestry (n=28), and astronomy (n=16). These categories accounted for a majority of responses. However, 68 respondents did not feel their project fell into one of these categories, and instead replied in their own words using the "other" field option. All but five responses were defined in clear, categorical terms that could be grouped under major headings to form response categories. These categories were climate and weather (n=7), human health and medicine (n=7), and environment (n=33). Three responses could be grouped under non-nature related projects, and two were labeled incomplete or unknown.

To assess which, if any, kinds of citizen science projects correlate with self-reported nature connectedness, wellbeing and sustainable behaviour, a chi-square test of independence was performed. Chi-square tests are a non-parametric test of the probability that an association between two categorical variables is the result of chance (Lund Research, 2013c). They provide a robust measurement of significance even when samples are not random, although they do not measure the size of association (Lund Research, 2013c). Due to insufficient sample size in each category, the assumption of adequate cell count was violated in every case. Therefore, the likelihood ratio was used to determine if significant relationships were present. No statistically significant relationships were found between kind of citizen science project and the self-reported variables.

Type of activity. The survey aimed to collect data on citizen science traits by asking respondents about the *types of activities* they are involved in when participating in citizen science. Using the same methods and process of analysis as above, 10 response categories were created (Table 7). The three most frequently reported citizen science activities were: 1) data collection, 2) monitoring/ watching/counting, and 3) data entry/reporting.

Table 7

Types and Frequencies of Citizen Science Activities Performed

		Number of Respondents (N=384)	Percent of Respondents
Type of Activities	Data Collection	275	71.6
	Monitoring/Watching/Counting	249	64.8
	Data Entry/Reporting	200	52.1
	Surveying	81	21.1
	Data Sorting	55	14.3
	Mapping	37	9.6
	Data Analysis	10	2.6
	Support	30	7.8
	Labour	29	7.5
	Unknown	7	1.8

Note: Bolded text indicates categories that were identified through analysis of open-ended responses.

Since it is possible to participate in multiple types of activities within one citizen science project, respondents were invited to identify all activities applicable to them. This resulted in 67 unique combinations of activities performed, varying from just one activity to seven. This caused the sample population to become too widely dispersed among categories for meaningful statistical analyses. Instead, this data was used to correlate *number of activities involved in* with self-reported increases in nature connectedness, wellbeing and sustainable behaviour. Somer's d tests indicated a weak, but positive and statistically significant association between the number of activities participants were involved in and all three self-reported variables: nature connectedness ($d = .171$, $p < .001$), wellbeing ($d = .112$, $p = .006$) and sustainable behaviour ($d = .098$, $p = .016$). Therefore, the more types of activities participants were involved in with their citizen science project, the more likely they were to also report higher levels of nature connectedness, wellbeing and motivation for sustainable behaviour because of their involvement.

Description of activity. The final citizen science trait question sought to obtain more in-depth information about participants' citizen science experience by asking respondents to *describe what they do in their citizen science* project. This question was entirely open-ended, with no multiple-choice options available. Responses yielded a wide diversity of replies related to various aspects of participants' citizen science experiences. Major themes, however, were identifiable. Emergent themes focused primarily around where activities took place (ie. indoors

or outdoors) and the elements participants interacted with while involved in the activity they were performing (ie. computers, students, or nature). Seven categories were identified through this process. Two categories involved different types of activities that took place outdoors, where participants were performing either active tasks, such as collecting water samples or digging up invasive plant species, or supervisory tasks, such as overseeing the active work of others. These categories were defined as “fieldwork – active” and “fieldwork –supervisory”. Three categories of activity took place indoors, and were termed “indoors – computer” (including desk or lab work), “indoors – active” (ie. collecting samples from indoor environments or submitting to a physical fitness test), and “indoors – communications” (ie. interacting with others in a teaching, promotional or administrative capacity). A category was created for citizen science participants who played a supportive or indirect role in projects, such as donating idle computer time, named “indirect support”. Finally, one category represented “incomplete or unknown” activities. Participants could be involved in one or several activities within one citizen science project, and therefore could be reported in more than one category.

A substantial portion of the study sample were participants in the fieldwork – active category (79%), representing the largest proportion. Just over one quarter reported performing indoor – computer activities (27%), with all other categories representing a very small portion of the sample: indoors – communications (6%); indoors – active (5%); supervisory fieldwork (3%); indirect support (2%). A chi-square test of independence found no difference between expected values and outcomes, indicating no significant association between categories of citizen science activities and the self-reported variables. These results were consistent when categories were grouped to allow for larger sample sizes (ie. indoor and outdoor), and when tests were applied only to the two largest categories (fieldwork – active and indoor – computer).

In summary, the results of inferential statistics in this section show statistically significant mean differences in self-reported increases in nature connectedness, wellbeing and sustainable behaviour on four project traits: 1) involvement in more than one project, 2) active involvement, 3) length of involvement, and 4) participatory hours per week. By contrast, no statistically significant associations were found between the self-reported variables and kind of project, type of activity, and description of activity.

Self-Reported Increases in Nature Connectedness, Wellbeing and Sustainable Behaviour - Qualitative

The questionnaire contained three open-ended questions that asked participants *why* they felt their citizen science experience had increased their sense of connection to nature, their overall wellbeing, or their motivation for sustainable behaviour. These questions aimed to uncover the key underlying elements influencing each variable in the context of citizen science, and to provide supplementary data from which to extract lessons learned for developing citizen science projects that strengthen nature connectedness, wellbeing and sustainable behaviour. The responses for each variable underwent identical analysis processes in Nvivo 11 as outlined in Chapter 3, to uncover major themes and sub-themes for why an increase in nature connectedness, wellbeing and sustainable behaviour was an outcome of citizen science participation.

Increased nature connectedness due to citizen science exposure. Respondents expressed a wide range of views for why they felt their citizen science experience had deepened or strengthened their relationship with nature. In all, 292 qualitative responses were received in response to this question. In-depth analysis identified several key elements and processes underlying these views, all of which converged on two overarching themes: experiential learning and unification. These themes emerged as constitutional aspects of the citizen science model, and the most fundamental for connecting people with nature. Several interwoven sub-themes were contained within each, most of which were interdependent or overlapping.

Experiential learning. Learning emerged as a fundamental element among responses to why citizen science exposure had strengthened nature connectedness. Specifically, respondents described learning that takes place in the real world, using real data that has real impacts, as the impetus for this outcome. In the context of citizen science, experiential learning was identified as the starting point for a multiple pathway process of personal transformation that would ultimately lead more than three quarters of the study sample to feel a deepened or strengthened connection with nature. Four sub-themes contained within the broader experiential learning theme were identified, including, 1) “seeing” nature, 2) developing an appreciation for nature and the interconnectedness of all things, 3) increased awareness of nature, and 4) motivation to protect nature. These sub-themes were reported as outcomes of the experiential learning aspect of citizen science activities, and contributed to the transformative process that more deeply connected participants to nature.

"Seeing" nature. The process of learning described by respondents in the context of citizen science projects took place primarily through repeated, experiential interaction with the natural world and with others. This process was enhanced by the real-world context in which citizen science activities take place, wherein greater meaning is attached to the information and experiences that citizen scientists are part of. "Seeing" nature first-hand in this context led participants to experience moments of reflection in nature, and to develop a new perspective of it as a result. To illustrate, one participant shared how her view of the natural world had shifted after "seeing" and learning about the endangerment of southern resident orcas: "Seeing their struggles has shaken me to my core about how vulnerable the planet is." Another participant reflected on how he felt changed by his citizen science experience in nature: "[Citizen science] got me on a glacier in Alaska – and the remoteness and beauty of my surroundings there left a permanent impression." These statements capture moments of reflection and personal change brought about by the experience of learning in citizen science activities. By being immersed in the subject matter, participants gained a different perspective of nature, and a deepened and more personal connection to it. As one respondent stated, "I got to see amazing things every day…. It was great to be immersed in such an incredible environment."

The interconnectedness of all things. Seeing and learning about the interconnectedness of nature was a major sub-theme among respondent views for why they felt their perspective of nature, and themselves, had been transformed. The response of one participant illustrates this well: "It makes you realize your[sic] part in the system, how much we are doing and it's[sic] effects on the world around us. It put everything in perspective." Another respondent stated simply, "Nature is about connections." For many citizen scientists, seeing these connections in context bridged what they had previously perceived as a separation between the human and natural worlds. One participant, for example, expressed how her experience in marine citizen science caused her to see the connections between lobsters, their environments, and humans:

> We all that participated changed our perception of seeing lobsters as a resource to see them as organisms with a life cycle that needed certain conditions in their environment to settle and thrive. We saw the connection to other lobster populations and to their preys and predators and felt the socio-economic impact (and conflict) in the fishermen communities.

Comments like these reflect not only a new understanding of the interconnectedness of nature, but also a sense of appreciation that has been gained from seeing this interconnectivity in a real-world setting. Appreciation gains were a widely-reported outcome of, or step in, the transformative process, embedded within respondent views for why they felt more deeply connected to nature. The following response from one participant illustrates this: "You see living animals as sentient beings, making decisions, creating beauty, needing to survive, and co-existing peacefully with other creatures." Views expressing the development of a broader and more inclusive view of the natural world were not limited to participants of terrestrial citizen science projects, but astronomy projects as well, suggesting that citizen science activities need not focus on immediate environments to impact upon participants' feelings of nature connectedness.

Increased awareness of nature. Experiential learning in citizen science enabled participants to become aware of elements in nature that, before citizen science, had been overlooked. A participant of marine citizen science reported: "I have become more aware of my surroundings and what is happening in nature." Such accounts were not limited to participants of activities that occur in nature; a citizen scientist who participated primarily in data sorting activities on a computer stated, "I see and watch things with more intent." In some cases, an increase in awareness inspired the desire for more knowledge, and several participants reported that they now ask questions and seek out more information on their own to expand their understanding of nature. This points to a desire to develop oneself in a way that fosters, or perhaps sustains, a connection with nature, and represents a continuation of the transformative process.

Motivation to protect nature. Seeing first-hand the issues that some citizen science projects aim to address had a meaningful impact on the learning process of many citizen scientists. These participants reported feeling not only more connected with nature, but more protective of it as well. As one respondent commented, "[Citizen science] has made me so much more connected to the ocean. I see things I never saw before. I understand the processes, the changes, the events. I want to be involved world wide in helping and saving our oceans and the sea life in them." Another citizen scientist described his transformative process, wherein experiential learning led him to feel a greater appreciation of nature, followed by a desire to protect it: "I've learned much about my local natural environment through my citizen science

experiences…. Understanding and appreciating what we have is an essential first step to protecting it."

In these cases, experiential learning led participants to feel not only more connected to nature, but also to have developed altruistic feelings toward it, indicating a reduced separation, or merging, of the self and nature, and a new sense of personal investment in and accountability for its wellbeing. As one citizen scientists shared: "It's reinforced my understanding of my own world view, which is my/our profound connection to and responsibility toward the natural world."

Unification. Along with experiential learning, unification emerged as a fundamental aspect of the citizen science experience, and a crucial element of the transformative process that led participants to feel more deeply connected to nature. Numerous respondents reported that participating in citizen science had been a unifying experience in many ways, between themselves and their communities, their families, science professionals, policy makers, advocates and organizations, as well as nature itself. Under the overarching theme of unification, three sub-themes were identified: 1) collective learning, 2) contribution and 3) empowerment. These sub-themes emerged as the means through which participants felt unified and thus, more deeply connected with nature.

Collective learning. Many participants reported that spending time with people who share their interests enhanced their learning experience by nurturing an environment of knowledge-sharing and collective effort. For example, one respondent stated, "I have gained much nature knowledge by being with like-minded individuals." Another respondent found that having her classroom take part in citizen science enhanced the nature connectedness of all those involved through both the collaborative and participatory aspects of the project:

> As we collected data and nurtured the Monarchs, we developed a deeper understanding of the species and the problems that it faces in today's environment. …Our students look forward to the project each year. It brings us together as a community and has influenced the culture of our school in a positive manner.

Other respondents felt that by working with experts on citizen science projects their knowledge of nature, and therefore their sense of nature connectedness, had been enhanced. The following responses capture this sentiment: "Getting involved, learning and sharing knowledge from other field experts" and, "I enjoyed being out in the field with a birding pro and learning about the

different birds and calls." The unification of people and groups over a common cause promoted collective learning as a means of finding solutions and addressing issues. It also enhanced the learning environment in a way that deepened participants' sense of connection with nature.

Contribution. Contribution emerged as a major sub-theme in the transformative process that more deeply connected respondents with nature. Embedded within many responses was the recognition that by participating in citizen science activities, volunteers are part of a collective effort to address a need – the objective of the citizen science project. Therefore, each participant plays a valuable role in the effort by contributing a small piece to the larger cause. For many, this attached more meaning to their activities and roles within citizen science projects. For example, one respondent felt more connected to nature because of the contributions he had made to his citizen science project, stating, "I have been able to actively contribute to the development of environmentalist research." Another participant of wildlife citizen science felt her efforts, although small, added meaning to her activities and made a valuable contribution to the collective effort of her citizen science project: "I am more focused in my wildlife observations--i.e. in my walks and birding outings. This focus makes my outings more pleasurable and meaningful. I also feel good that I am contributing a small something to science…." For others, citizen science participation was a complement to an activity or hobby they already enjoyed. By combining the two, greater meaning and purpose were attached to the activity. A respondent who enjoyed SCUBA diving stated that participation in marine surveying and reporting for citizen science, "made diving seem new again." Similarly, a female hiking enthusiast related her increased nature connectedness to the contributions she now makes while enjoying her hobby: "Now that I work outside as a citizen scientist I feel better about using my free time contributing data and useful information regarding the things I care about and love the most."

Citizen science activities were a way for participants to feel they were contributing to a greater good, by playing a small part in something meaningful and larger than themselves. "I'm a part of the greater good – a contributor," stated one respondent. For many, these feelings of altruism were brought about by the unifying experience of citizen science participation, and strengthened participants' connection with nature. A participant of avian citizen science reported that, "I am actually able to contribute to something other than just enjoying nature for myself." Another respondent felt unified not only with other people, but with other forms of life: "Being involved and feeling like a difference can be made. We need to be the voice for all living things,

as we share their world and it would be empty without the natural beauty." Others were aware of the larger impact their contributions would make, such as a participant of marine turtle monitoring: "I'm contributing to the science and the evidence that managers can use to better protect the area." Another respondent stated, "Knowing that the data I collect can contribute towards a 'greater good' positive influence on our scientific understanding, policy, and, ultimately, conservation initiatives." In response to *why* participants felt more connected to nature because of their citizen science experience, these views reveal a profound sense of unification, collaboration, and in many cases altruism, that is embedded within the experience of citizen science, bringing together participants with scientists, with communities of practice, with nature itself, and with the wins and losses of an effort that aims to address environmental issues and democratize scientific progress. Furthermore, they are indicative of a sense of empowerment that had been gained from the contributions these respondents felt they had made by participating in citizen science.

Empowerment. In some cases, empowerment was explicitly cited as an outcome of the citizen science experience, and a means by which several respondents felt more connected to others and to nature. Empowerment was expressed not only in terms of the skills and knowledge participants had gained, but also in terms of the broader positive impacts that can occur from citizen science projects, as well as their recognition of the critical role they had played in those outcomes. For example, a participant of large-scale avian research stated the following: "Contributing to science feels empowering and the right thing to do." Another reported that, "Knowing how the data is used and getting info back from scientists is very empowering." This same respondent reported that she felt more motivated to protect nature and help solve environmental problems because, "Citizen science involvement brings you from a place of feeling that there's nothing you can do, to knowing that your actions can have a positive impact especially added with other's actions." Empowerment gained through citizen science was also implicated as a source of inspiration and motivation to empower and inspire others to develop a deeper connection with nature: "Empowering me to develop my own skill set that I can use where ever[sic] I go such as identifying species. […] I was able to inspire others to get outside and look around." Another citizen scientist shared that by strengthening his connection to nature through citizen science activities, he now enjoys "empowering youth by involving them in monitoring of their local rivers and getting them out kayaking as a way to further engage in

observation and appreciation of local watershed conditions and the need for stewardship." One respondent explicitly commented on the transformative process that she enjoys facilitating in others: "It's a great way to encourage people who do not see themselves as environmentalists start to transform simply because of the fascination of detail in biodiversity and natural resources."

Overall, a deepening or strengthening of nature connectedness due to citizen science participation was indicated, overwhelmingly, as a result of experiential learning and an underlying sense of unification. These overarching themes emerged as both constitutional aspects of the citizen science model, and the primary means through which participants developed a deeper connection with nature. Participants reported not only learning about nature, but the integration of that learning within the self and therefore a new lens through which to view the natural world, their place within it, and in some cases, their responsibility towards it. In this way, collective and experiential learning proved a powerful, synergistic force for catalysing a process of personal transformation that led participants to feel more deeply connected to nature. The following comment from one respondent provides a good summary of how these elements interact within the citizen science experience to connect people with nature:

> Because by getting involved in any citizen science project I take ownership of the problems and threats and ncrease[sic] my understanding about… habitats and endangered species adding to information and increasing stewartship[sic]. The problems are shared amongst participants and are no longer too big or anonymous to tackle - it's a community of interest effort.

Figure 2 summarizes the interactions that take place within the context of citizen science to generate deeper feelings of nature connectedness. Many of these same themes and outcomes carried over into respondents' views on why they felt their citizen science participation had given them a greater sense of overall wellbeing and life satisfaction, and motivation for sustainable behaviour, discussed in this next sections of this chapter.

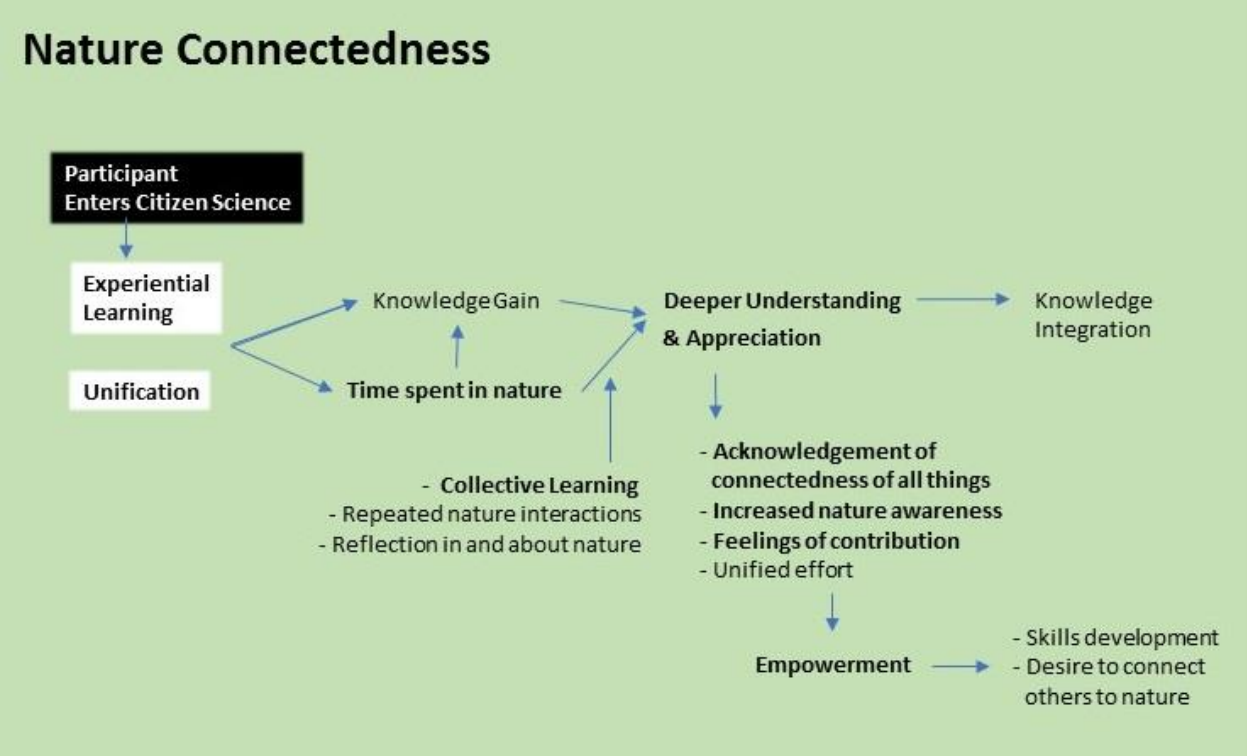

Figure 2. The transformative process of nature connectedness within the context of citizen science. Based on participants' open-ended responses to why citizen science participation strengthened nature connectedness. Black background represents the beginning of the process. White background represents major themes. Bolded text represents sub-themes.

Increased wellbeing due to citizen science exposure. Three quarters of the study sample reported feeling a greater sense of overall wellbeing and life satisfaction as an outcome of citizen science participation. To gain a more in-depth understanding of the citizen science-related factors influencing this outcome, respondents were asked to describe, in detail, what it was about their citizen science experience that had caused them to feel this way. In-depth analysis of the 284 responses provided revealed four major themes impacting upon wellbeing in the context of citizen science: 1) connection with nature, 2) personal enrichment and growth, 3) collaboration and community building, and 4) meaningfulness. These major themes were, in most cases, interwoven or significantly overlapping.

Connection with nature. A deepened sense of nature connectedness due to citizen science participation was commonly cited as a reason for respondent's reported increases in wellbeing. In response to why citizen science participation had positively impacted upon wellbeing, one respondent stated simply: "connection to nature." Similarly, several respondents

replied with, “see above,” referring to their response to the previous question – *why citizen science participation had deepened their sense of connection with nature*. This reference implied that, for them, the two constructs were perfectly positively correlated, with one directly impacting upon the other.

Less direct references to a greater connection with nature, or the wellbeing benefits of increased interaction with nature, due to citizen science included remarks such as, “involvement in citizen science projects is… an extra reason to get out and enjoy nature, regardless of where I am at the moment,” and “Being out by the ocean always makes me feel better.” For some, citizen science provided them with an opportunity to be alone with nature, inducing a state of calm, peace and meaningful reflection that contributed to their overall sense of wellbeing. Citizen science involvement as a reason to get “away from technology” and outside doing “environmental work” with others was also indicated as being beneficial for wellbeing, as was “carrying out practical/physical tasks and working in natural lighting as opposed to sitting in an office.” These views highlight a human need for disconnection from the day-to-day digital world, and reconnection with the natural world in a hands-on, active and meaningful way as a means to improve overall wellbeing and life satisfaction.

Personal enrichment and growth. Wellbeing was also experienced as an outcome of personal enrichment gained from citizen science participation. Some respondents expressed wellbeing in terms of increased feelings of self confidence, independence, and pride. While others felt that citizen science participation had impacted their wellbeing by providing them with hope for the future, a winter activity, or a personal legacy to leave behind. The acquisition of new skills and insights through citizen science led several respondents to make significant life changes, and in some cases led to new and fulfilling careers or job opportunities. Citizen science participation as a stress reliever and mechanism for coping with life’s difficulties also reportedly contributed to participants’ wellbeing, as did the sense of purpose it provided for some in activities they already enjoyed doing, such as SCUBA diving. The most commonly cited reason for increased overall wellbeing as a result of personal enrichment was enjoyment. Participants expressed enjoyment in terms of “the work” of citizen science activities, “helping”, “of the project on a scientific level”, “being part of the process”, “working in the field”, and “the problem solving” that citizen science activities sometimes require. Personal enrichment was

embedded throughout the other three major constructs that emerged as facilitators of wellbeing, most significantly overlapping with collaboration and community building.

Collaboration and community building. A large proportion of respondents commented on the impact citizen science participation had had both on their communities, in terms of social bonding and building cohesion and awareness around conservation issues and solutions, and on their feelings of connection with others in unity. Meeting new people and engaging in social interaction over shared interests was the prevailing reason given for why wellbeing gains were experienced. Some expressed that social interaction through citizen science participation fulfilled their needs for belonging, sense of worth, and connection with others. One respondent who participates in water quality monitoring of streams expressed how sharing citizen science with youth positively impacts his wellbeing: "It is satisfying to get feedback from kids about how they enjoy river experiences that we do and the difference it makes in their appreciation of the outdoors." Similarly, another respondent felt his wellbeing improved by sharing citizen science with others, stating "Completing and assisting others with projects and seeing their attitudes change was satisfying."

Some citizen scientists commented on the benefits of experiencing a shared sense of camaraderie by rallying around a meaningful cause through citizen science activities. Teamwork was valued not only in terms of other citizen science participants, but in helping scientists as well, as one respondent stated, "I like helping people and being part of a team, so being a citizen scientists[sic] is rewarding since I am helping a scientist collect her data (and helping her organization)." In most cases, increased wellbeing as a result of teamwork and camaraderie were referred to in terms of direct interaction with others, usually during shared fieldwork in a natural setting. Although participants of citizen science projects not requiring fieldwork or direct interaction with others also reported gains in wellbeing, these participants primarily cited the contributory and meaningful nature of their citizen science work as the cause. Comments from these respondents included, "doing citizen science is a much better use of my time than other activities, like watching tv or playing games," "feels like I'm doing something important," and "it gives me something proactive to do." These statements allude to feelings of personal enrichment and satisfaction that are gained when an activity has meaning attached to it which, in this context, was provided by citizen science.

Meaningfulness. Meaningfulness was found among nearly all reasons for why wellbeing was improved due to citizen science participation. Meaning was cited in terms of the work or activity being done, and the ways in which citizen science provides volunteers with ways to participate in research, even as non-scientists. One participate of a project related to solar storms sorted data while also helping students learn to do the same. He found meaning in both by saying, “Citizen science sites provide the opportunity for ordinary people with no science background to meaningfully engage in actual scientific work.” He added that helping students also contributes to his wellbeing: “Their sense of discovery and joy adds to my own considerably.” Other respondents found meaning in the impact the work would have or the contribution it would make to a greater good. A female participant reported that she has shifted her career toward citizen science, which has added greater meaning and wellbeing to her life: “My life and career is now also linked to citizen science, which is a much more meaningful thing to do than most jobs.” The activities of citizen science were found to be meaningful to many participants, as were the social interactions they had with others by being involved. One respondent shared that citizen science is an, “Opportunity to do something meaningful, and interact with like-minded people.” Another participant reported that his vacation habits have changed since joining citizen science, stating, “I've become a part of a community and made great friends through this work. My big annual vacation for the last several years have been to go on organized trips and survey. These trips are more meaningful and fun than what I did before.” The social interactions and forming of new connections that arose from taking part in citizen science projects, or the deepening of already existing connections with others or with the natural world, was highly valued among respondents who reported wellbeing gains.

Meaningfulness emerged as a major theme of increased wellbeing in the context of citizen science. Furthermore, it was found across responses from participants of all distinguishable citizen science traits. Its pervasiveness is indicative of a fundamental need for meaning in the pursuit of overall wellbeing and life satisfaction.

Figure 3 illustrates the major themes that emerged from participants views on why citizen science had improved participants’ overall wellbeing, as well as the reported outcomes that resulted from each.

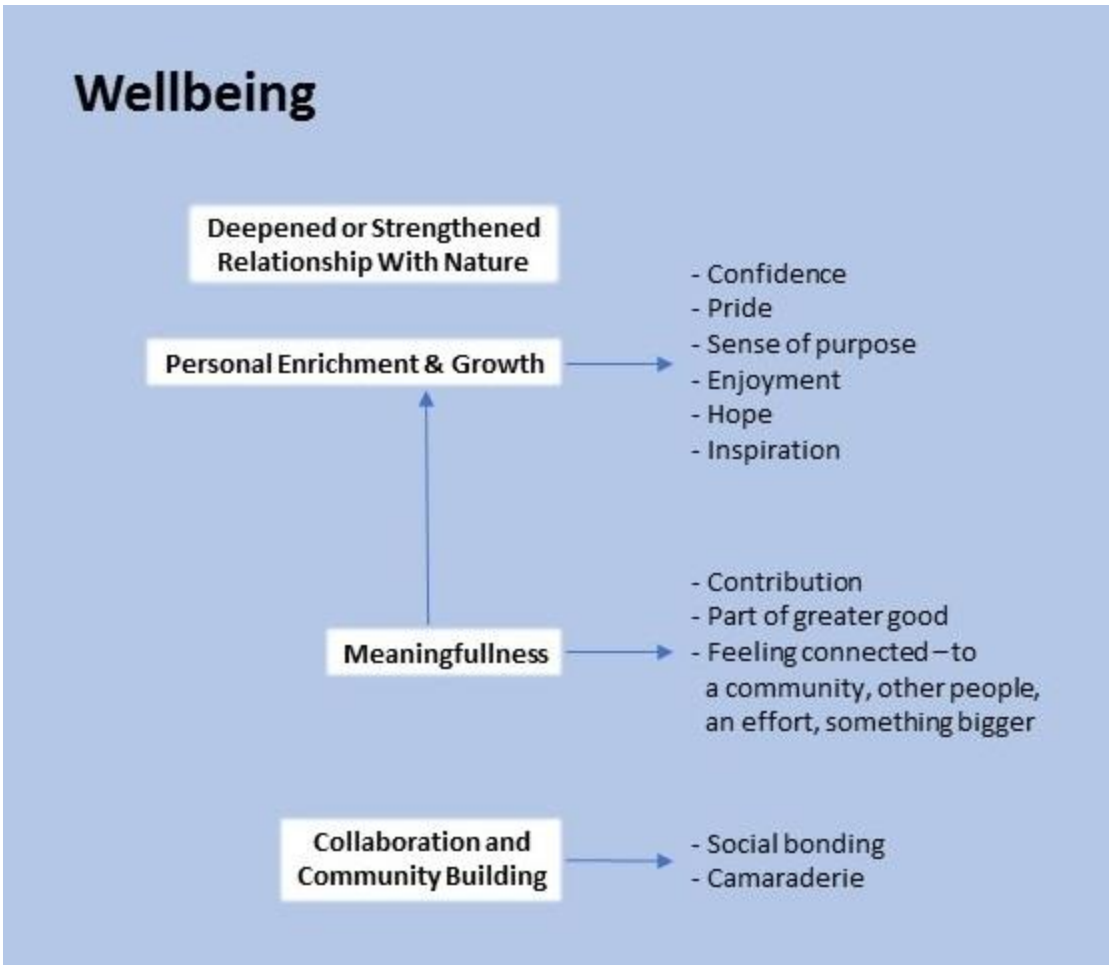

Figure 3. The major themes of wellbeing within the context of citizen science. Based on participants' open-ended responses to why citizen science participation improved overall wellbeing or life satisfaction. White background represents major themes, or reasons, reported for why participants experienced improved wellbeing as a result of citizen science participation. Un-highlighted text represents outcomes related to each theme.

Increased motivation for sustainable behaviour due to citizen science exposure.

Since this study sought primarily to identify how citizen science projects could effectively foster sustainable behaviour, survey participants were asked to describe why they felt citizen science had influenced their motivation to protect nature or help solve environmental problems. More than 70% of respondents reported an increase in motivation for environmental action, with 288 providing qualitative explanations for why this impact had occurred. Deeper analysis of respondent views and verbiage used revealed two key themes – appreciation and inspiration – embedded throughout, marking a process of personal transformation that had occurred as an outcome of citizen science participation.

Appreciation. Appreciation was found to be either newly developed or expanded upon through citizen science participation, and acted as a motivating force for sustainable behaviour. In all cases, appreciation was preceded by learning, which was gained through the direct, hands-on learning experience. Experiential learning, although not explicitly cited among responses, emerged as an antecedent to appreciation by contextually bringing participants into closer proximity with the physical and theoretical aspects of the natural world, resulting in a deeper and more self-integrated level of awareness and understanding of it. In this sense, appreciation is a more reflective and philosophical experience than mere knowledge acquisition in that it is more sensory, containing within it expressions of gratitude, acknowledgement, and in some contexts obligation and love. It is therefore a stronger and more profound driver of internally-motivated behaviour than knowledge alone. Respondents reported having gained through their citizen science experiences, an appreciation for issues around sustainability, environmental degradation, negative human impacts on nature, threats faced by wildlife, and the need for more research and environmental advocacy by “seeing first-hand” and “being involved” in the efforts to address these issues. The experiential knowledge gained through citizen science activities caused participants to critically reflect upon and begin to appreciate the functions of nature, the connectivity of the macrocosm, and the role that citizen science – and therefore themselves – are playing within it. This process led many respondents to also reflect upon and appreciate their own roles in these contexts, as well as the impacts their actions have. For a female participant of conservation projects, citizen science involvement explicitly led her to ask herself what else she could be doing to protect nature: “[My] eyes are opened to more impacts. ...As a citizen scientist, you observe and start to wonder and ask "why", then "what more can I do?" Additionally, a participant of wildlife projects felt motivated after see the effects of unsustainable human behaviour, stating, “[I] see the damage we cause, and it makes me aware of my own actions.” These statements reflect not just the development of knowledge and appreciation, but also feelings of altruism and advocacy.

Notions of altruism and advocacy frequently emerged from the narratives of citizen scientists who felt more motivated to take sustainable action. Respondents expressed a “need to give back”, “make a contribution”, “be part of the search for answers” or “make a difference” because of their exposure to citizen science. In almost all such cases, these feelings were precipitated by a learned appreciation for the pervasiveness and severity of negative

anthropogenic impacts on nature which, in turn, prompted feelings of accountability. To illustrate, a participant of wildlife citizen science stated, “When I see that animal species are dying off because of problems that are man-made and can be managed without a whole lot of effort from each citizen, it motivates me to try to do my part to help.” Another female respondent said that, “It has increased my awareness of human impact on nature and to figure out ways to offset this impact.” Several citizen scientists reported that, because of their citizen science experiences, they felt inspired to take political or civil action, increase communication with their local and national level legislators, and make demands for local solutions. These sentiments reflect a motivation for environmental action that stems from feelings of altruism and advocacy for the natural world, and a heightened sense of ownership for the problems faced by nature.

Not all appreciation gains arose from seeing and learning about how the natural world is being negatively impacted by humans. Many reported that the experiential learning provided through citizen science had fostered in them an appreciation for the beauty and elegance of nature. “You come to realize how much biodiversity exists even in a relatively small space,” was one such view. For another respondent, citizen science activities were a reminder to appreciate the bigger picture: “It took me out of my world and reminded me we live on a living planet.” One respondent reflected on her experience at seeing both the positive and negative aspects of experiential learning through marine citizen science: “Each time I go diving, I see the beauty of the underwater world and feel a strong desire to protect it. Conversely, we also see the damage being done to the oceans by pollution, trash and climate change--so, both of these serve as strong motivating factors to protect the underwater environment.” In these contexts, citizen science acted as a conduit through which a process of reflection took place, and a new relationship with the natural world could be formed. Embedded within these statements, and paramount to motivating sustainable behaviour, is an underlying sense of appreciation that has been gained through the experiential learning process in the context of citizen science activities. This transformative process is exemplified by the following response: “When you understand more, you realize how important every piece of nature contributes to another. Having hands on with knowledge makes you more open to the variety found in nature and empathetic and protective.”

Some respondents identified specific sustainable actions they had taken in response to what they had learned in citizen science projects. “Since we began tagging Monarchs we have

now planted Milkweed and other native flowering species in our yard to help not only the Monarchs but also all pollinators. We have done a lot of educating and sharing with others about these experiences," was the reply of one respondent. Another changed his eating habits after learning of the plight of whales who get entangled in crabbing gear and suffer severe injury or death as a result. These statements represented a large proportion of views in which citizen science had fostered an appreciation for wildlife under threat from the negative impacts of human behaviour. This underlying appreciation – the result of experiential learning – motivated these respondents to change their behaviour in response.

Inspiration. Inspiration was also widely reported among participants as having a powerful influence on their motivation for sustainable behaviour. Specifically, respondents felt inspired by the knowledge, dedication and actions of others in their citizen science networks, and felt more motived to protect nature as a result. This impact was due, in large part, to the collaborative and social aspects of citizen science projects. Overwhelmingly, respondents reported feeling inspired and motivated by the actions and dedication of others. "Seeing the personal commitment of others to do better," and "contributing to science as a group is inspiring," were just two such views. For many, inspiration was derived from a sense of camaraderie and shared effort that was fostered through many citizen science projects: "It feels more do-able when you have a whole community of people rallying for an environmental cause!" Comments like these also speak to a gained sense of self-efficacy to perform environmentally protective actions. Several respondents reported that seeing others respond positively and with excitement to new learning experiences through citizen science had been a source of inspiration that motived them to continue working to protect nature and help solve environmental problems. A female participant of wildlife citizen science reported that, "Seeing peoples[sic] reactions to seeing a unique bird or wildlife situation (ie. an active hawk nest) makes me realize how easy it can be to make connections for people with nature. That excitement motivates me to continue the work I am doing." For some, working with experts or highly knowledgeable and impassioned leaders was a source of inspiration which motivated participants to protect nature. "The connection and learning opportunities gained from knowledgeable science partners - and the friendships among kindred spirits - program managers and other citizen scientists," was one reply to why citizen science participation had motived sustainable behaviour. Not all inspiration was precipitated through direct contact with others. Participants

who performed desk or computer work by themselves also reported feeling inspired and motivated to protect nature through action. This was the case for one respondent who reported feeling inspired by the writings of researchers who came before her: “In my research, I can see what lead to extinction of species through personal accounts by the various people who discovered them. Their wonder of nature is communicated through their writing, which inspires me to do more to protect the world around me.” Underlying these responses is the presence an additional element within the citizen science experience that is motivating sustainable behaviour: feelings of belonging to a community of practice. That is, feeling membership to a group of people who share a domain of practice, be it an attitude or activity, and in learning collectively through sustained interaction and the sharing or resources, develop expertise in that domain. Therefore, through frequent exposure to citizen science activities, participants developed feelings of membership to a group whose attitudes and behaviour they either shared or adopted through practice and repeated interaction. Respondents experience more motivation to take sustainable action when citizen science projects expose them to: 1) practices or information that promotes sustainable behaviour (ie. the damaging effects of human behaviour on the environment), 2) ways in which these effects can be alleviated, and 3) impassioned, knowledgeable and influential mentors. A summary of the major themes and interactions taking place within the process of personal transformation that increased participants’ motivation for sustainable behaviour is provided in Figure 4.

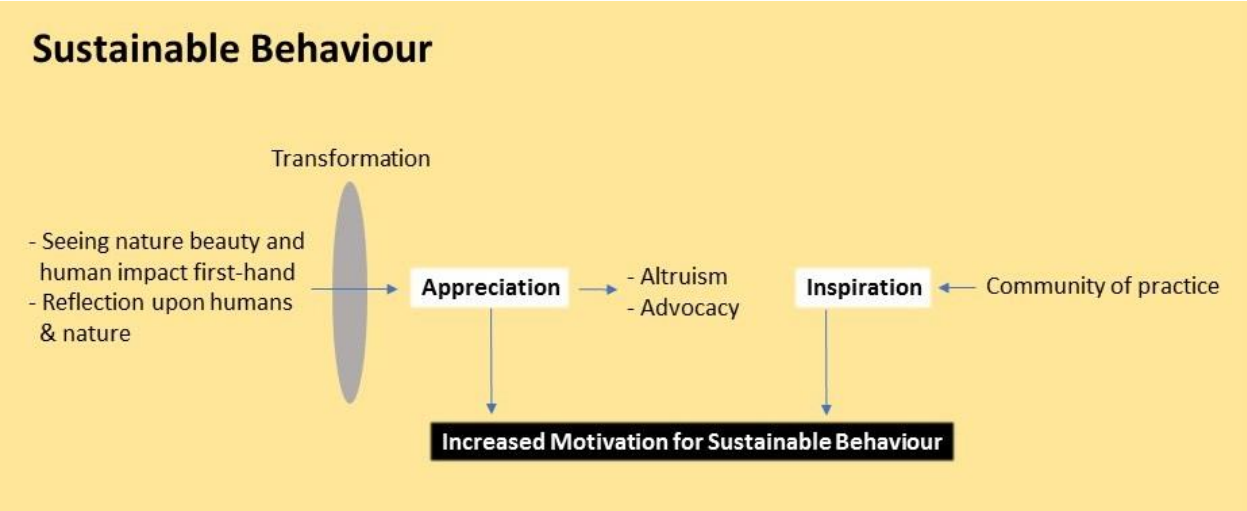

Figure 4. The major themes of sustainable behaviour within the context of citizen science. Based on participants' open-ended responses to why citizen science participation increased motivation for sustainable behaviour. White background represents major themes, or steps in the process that led to increased motivation for sustainable behaviour. Un-highlighted text represents influencers or outcomes related to each theme.

Summary of Findings

To address the first objective of this study, an examination of the relationships between overall nature connectedness, wellbeing and sustainable behaviour in the context of citizen science was performed using correlational analyses. The results of these tests found no association of any significance between these three composite variables. This is likely due to the lack of variability among the study sample. Correlational analysis of self-reported increases in each variable as a result of citizen science participation, however, found strong, positive associations among each. Furthermore, the p-value for each correlation was < .001, indicating a less than 0.1% chance that these associations were found due to chance if, in fact, no associations were present.

The second objective of this study was to identify which project traits, if any, correlate with self-reported increases in nature connectedness, wellbeing and sustainable behaviour. Inferential statistics found that involvement in more than one citizen science project, current active involvement in a citizen science project, length of involvement, number of different types of activities performed, and hours per week, all positively correlated with each of the three variables at the 95% confidence level. No statistical associations were found between the three variables and kind of citizen science project and description of activity.

Finally, open-ended responses on why participants reported experiencing gains in nature connectedness, wellbeing and sustainable behaviour as a result of their citizen science experience were analysed to add depth to statistical results, and to satisfy this study's third objective: to extract lessons learned for developing citizen science projects that strengthen nature connectedness, wellbeing and sustainable behaviour. Increased nature connectedness due to citizen science involvement was found to have been heavily influenced by the experiential learning and unifying aspects of citizen science projects. Increased wellbeing due to citizen science participation was driven by four underlying factors: 1) connection with nature, 2) personal enrichment and growth, 3) collaboration and community building, and 4) meaningfulness. Increased sustainable behaviour due to citizen science participation was underpinned by feelings of inspiration and a developed sense of appreciation for nature, which were reportedly gained in the context of citizen science. A great deal of overlap and interdependence was present between each of these emergent themes across all three self-report variables.

Figure 5 summarizes a model for the process of personal transformation reported by the open-ended responses from participants of citizen science. In this illustration, participants enter the process at the top left corner where they are exposed to the fundamental experiential learning and unification aspects of the citizen science model. Depending on their individual citizen science experience, and their personal responses to these experiences, some then proceed through one or more alternate pathways outlined, experiencing increases in one, two or all three variables.The quantitative findings suggest this process is strengthened through deep, consistent exposure to citizen science activities.

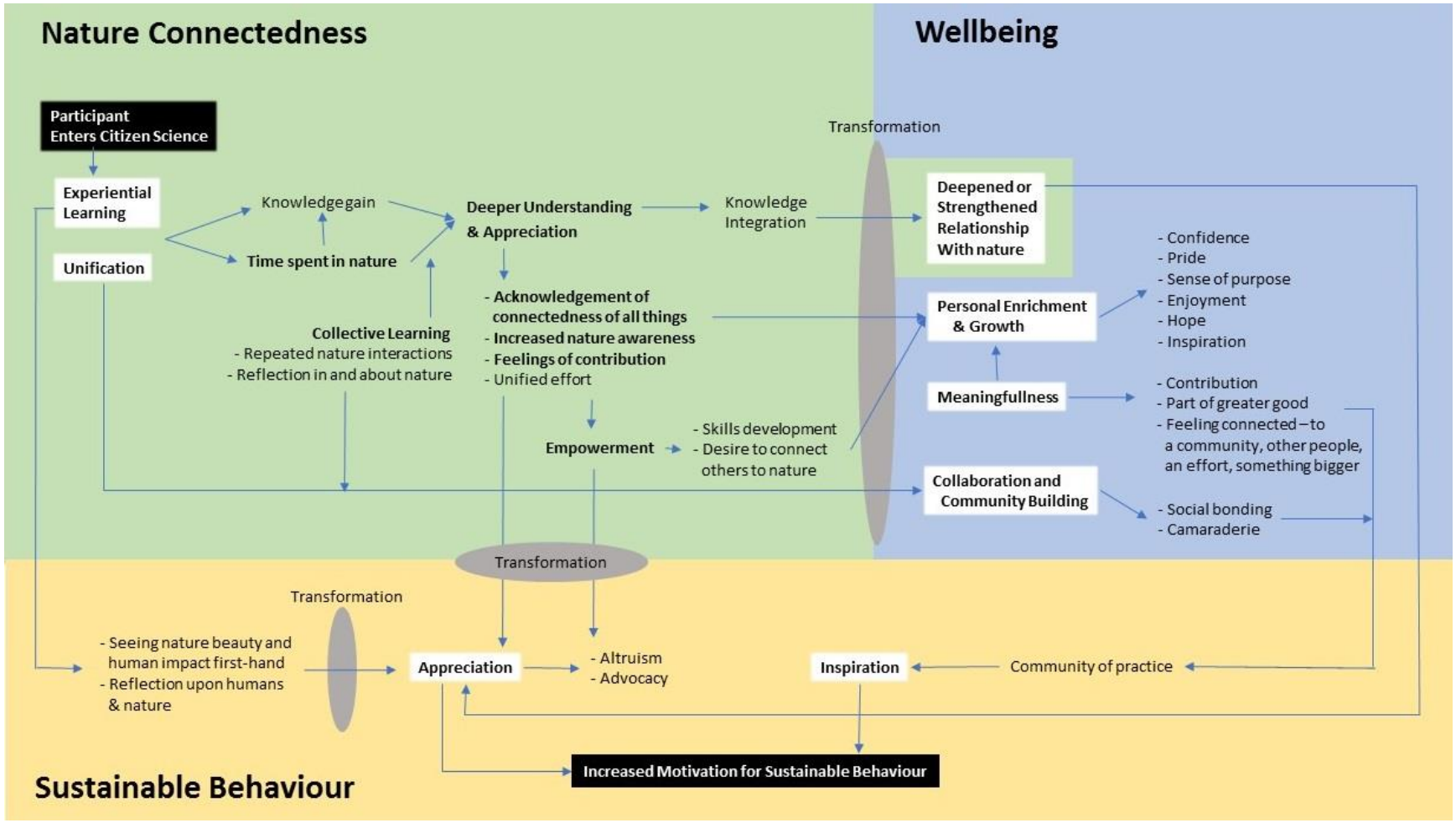

Figure 5. The alternate pathways in the transformative process that leads participants to experience strengthened nature connectedness, improved wellbeing, and/or increased motivation for sustainable behaviour within the context of citizen science, as reported by qualitative findings. Quantitative findings suggest this process is strengthened by deep, consistent exposure to citizen science activities. Black backgrounds represent starting and end points in the process. White backgrounds represent major themes related to each variable, and highlighted text represents sub-themes related to each variable.

Discussion

As the negative environmental impacts due to unsustainable human behaviour accrue, the need for effective and efficient models of conservation interventions grows. Traditional methods based solely on the dissemination of knowledge have proven largely ineffective at motivating sustainable behavior change, and overlook the socially and psychologically embedded systems and trends that are at the root of unsustainable behaviours (Martín-López & Montes, 2015). If conservation interventions are to successfully address sustainability issues, a more holistic and socially-integrated approach is needed. The citizen science model provides a good framework within which to study how to improve the efficacy of interventions that aim to influence sustainable behaviour because of traits inherent within its design that are supportive of such an approach. These traits include the following: 1) it usually takes place in the context of the natural world; 2) it is widely accessible to all demographics, is highly collaborative and usually requires no special skills; 3) participation is free and voluntary; 4) it joins professional scientists with citizens in real-world settings using real data to address social-environmental problems; 5) it significantly contributes to scientific research and expands environmental knowledge; and 6) it is rapidly expanding and innovating (Kobori et al., 2016). These traits align with previous studies that assert the need for frequent and sustained interaction with nature (Theimer & Ernst, 2012), conservation activities that are social and collaborative (McNeely & Scherr, 2003 as cited in Pretty & Smith, 2004), and information dissemination through experiential learning (Shepard & Speelman, 1985) to influence motivation for sustainable behaviour. Although research conducted on citizen science has focused primarily on scientific and environmental outcomes, this study looked at the impacts of citizen science exposure upon individual participants. Specifically, the relationships between nature connectedness, wellbeing and sustainable behaviour in the context of citizen science were examined. This chapter makes recommendations for the development of more effective models of influencing sustainable behaviour in citizen science projects, and other conservation interventions, based on study findings and existing literature.

The relationship between nature connectedness and wellbeing has been established in academic literature for decades. While many practitioners have begun to integrate this theory into practice for its health and wellness benefits, the scientific community has failed to grasp the significance of nature connectedness as a method for achieving conservation goals (Hartig, Mang, & Evans, 1991; Maller, Townsend, Pryor, Brown, & St Leger, 2006). Similarly, studies are plentiful in support of a strong relationship between nature connectedness and sustainable behaviour (Geng et al., 2015; Mayer, F.S., Frantz, C.M., Bruehlman-Senecal, E., & Dolliver, K., 2009; Howell, A. J., Dopko, R. L., Passmore, H.,

& Buro, K., 2011), and new research suggests there is a reciprocal relationship between wellbeing and sustainable behaviour (Koss & Kingsley, 2010; Corral-Verdugo et al., 2011; Kaida & Kaida, 2016). A look at these relationships within the citizen science model could help identify more efficient ways to capitalize on them, and inform the development of more effective means for promoting sustainable behaviour by addressing the socially embedded causes of environmental degradation. This framework informed the central purpose of this study, which was guided by three main objectives:

1) To examine the relationships between nature connectedness, wellbeing and motivation for sustainable behaviour in the context of citizen science;
2) To identify which project typologies and traits, if any, correlate with higher self-reported levels of nature connectedness, wellbeing and motivation for sustainable behaviour as a result of citizen science participation;
3) To extract lessons learned for developing citizen science projects that can deepen nature connectedness, improve wellbeing and increase motivation for sustainable behaviour.

Nature Connectedness, Wellbeing and Sustainable Behaviour

This study first sought to examine the relationships between nature connectedness, wellbeing and sustainable behaviour in the context of citizen science. Previous literature indicates a positive relationship between nature connectedness, wellbeing and sustainable behaviour. Accordingly, I expected to see similar correlational relationships among these variables in the study sample. The findings, however, were at odds with the literature and only very weak, or no associations at all, were described by the results of correlational analyses. This is likely due to the lack of variability among sample scores, known as range restriction (Goodwin & Leech, 2006), and does not necessarily imply that no relationship exists. Rather, the narrow range of scores restricts the correlation analysis from capturing any existing relationships (Goodwin & Leech, 2006).

The sample showed generally high levels in all three composite variables. Since citizen science activities are volunteer and primarily nature-centric, this finding can likely be attributed to the type of people who are attracted to citizen science activities – people who demonstrate higher general levels of nature connectedness, wellbeing and sustainable behaviour and are therefore already motivated to participate in citizen science activities.

Deep, Consistent Participation in Citizen Science is Key

One of the objectives of this study was to identify which aspects of the citizen science experience most strongly correlate with increased nature connectedness, wellbeing and sustainable behaviour. With a litany of previous research in support of positive associations among these variables,

I expected to find a great deal of overlap among citizen science traits that correlated with each. Indeed, the findings showed complete overlap, and among the five citizen science data points identified, all three variables most highly correlated with the same category within each. Self-reported increases in all three variables were most frequently reported by citizen scientists who were: 1) active versus inactive, and 2) involved in more than one project, 3) in more than one activity within a project 4) for a longer period of time, and 5) during more hours per week. The results suggest that deep, consistent participation in citizen science activities is key to bringing about positive outcomes in nature connectedness, wellbeing and sustainable behaviour and mitigating negative environmental impacts. Given that almost 80% of survey respondents were participants of active fieldwork occurring outdoors and primarily in natural settings, these findings are consistent with the literature, which suggests that frequent interactions with nature and time spent outdoors are associated with stronger feelings of connection to nature (Theimer & Ernst, 2012), a greater sense of happiness and overall wellbeing (Townsend, 2006), and environmental stewardship including sustainable behaviours (Chawla & Cushing, 2007). Furthermore, investigative studies on the efficacy of environmental education programs have identified duration of involvement and opportunities to perform actionable skills as key components of programs aimed at influencing pro-environmental attitudes and behaviours (Chawla & Cushing, 2007).

Citizen Science Strengthens Nature Connectedness, Wellbeing and Sustainable Behaviour

Citizen scientists do experience subjective (self-reported) increases in nature connectedness, wellbeing and sustainable behaviour because of their participation in citizen science projects, with nearly 60% reporting increases in all three. These constructs were found to be strongly associated with each other in the context of citizen science. Feeling connected to the natural world is linked with greater overall wellbeing (Sandifer et al., 2015) and more motivation to act sustainably (Geng et al., 2015), and there is evidence of a reciprocal correlational relationship between wellbeing and sustainable behaviour (Kasser, 2009; Hartig, & Bowler, 2001; Corral-Verdugo et al., 2011; Marks et al., 2006). The open-ended responses for why participants felt citizen science exposure had increased their nature connectedness, wellbeing and sustainable behaviour, uncovered overlapping themes and sub-themes that suggest these constructs are highly interrelated, with each influencing and being influenced by the others. Through examination of the processes and reflections described by respondents, I was able to identify some of the ways in which these themes interact, and uncover a multiple pathway process of personal transformation taking place within the context of citizen science that begins with nature connectedness.

Nature connectedness. Two major themes were identified as the primary underlying elements forming the basis of reports for strengthened nature connectedness. These were experiential learning and unification – both constitutional aspects of the citizen science model. Experiential learning has long been touted as the preferred model for delivering environmental education programs since, as Balmford and Cowling (2006, p. 694) assert, "…even if all the other building blocks of effective conservation are in place, we will not succeed unless the general public cares, and they are unlikely to care if they no longer experience nature directly." Numerous studies have shown that experiential environmental education in outdoor settings can effectively promote pro-environmental attitudes and behaviours (Shepard & Speelman, 1985; Deurden & Witt, 2010), increase feelings of connection with the natural world (Dresner and Gill, 1994), and improve understanding of ecological systems and environmental values (Mittelstaedt, Sanker & VanderVeer, 1999). In this study, experiential learning enabled volunteers to feel they were participants in the natural world and to "see" nature first-hand with a new perspective. This enhanced their learning of natural and ecological systems and for many, provided opportunities for sensory experiences of nature, which precipitated moments of personal reflection and the development of a deeper sense of appreciation for nature and the interconnectedness of all things, including the self with nature. This process of nature connection was similarly reported by Richardson, Hallam and Lumber (2015), who found that sensory experiences in nature was a dominant theme in a study of nature connectedness. Based on participants' written reflections on nature, they argue that "sensations are the sensory moment of human-nature interaction and relationship…the point where human and nature is experienced as one" (Richardson, Hallam & Lumber, 2015). Sensory experiences in nature, such as feeling captivated by a landscape or struck by birdsong, determine our emotional attitudes toward nature which, according to CNT (connectedness to nature) theory, is one of three dimensions that determine how our relationships with nature are formed. Actions and experiences in nature (behavioural) and knowledge about nature (cognitive) define the other two, and there is consensus that all three dimensions are most strongly influenced by frequent positive interactions with nature (Theimer and Ernst, 2012). Within citizen science projects that take place in natural settings, all three dimensions are engaged through the educational, sensory, and action components of citizen science activities. Respondent views confirmed that citizen science experiences related to each of these dimensions impacted upon nature connectedness, and 77.9% of study participants reported a deepened or strengthened connection with nature as a result. Combined with the quantitative results that show frequent, sustained exposure to citizen science activities increases nature connectedness, this study lends additional strength to CNT theory.

The other overarching theme was unification, which relates primarily to feelings of cohesion and collaboration with respect to both humans and nature. Three sub-themes were contained within this larger theme, all of which strengthened nature connectedness. These were collective learning, contribution, and empowerment, which were found to be highly interconnected. The main pathway by which these themes interacted began with collective learning, which not only enhanced participant's knowledge- and skills-building experiences, but also increased their awareness that they are but one small piece in a larger collective, be it the effort to address environmental problems or gaps in research, a community of practice, or the collective of nature itself. Learning the value of their contributions and realising both their individual and collective competencies within citizen science led participants to feel empowered, and for some, motivated to empower others through a similar process. In this way, collective learning, contribution and empowerment synergistically supported nature connectedness. Collective learning in citizen science provides participants with opportunities to socially engage with environmental discourse in a pro-nature forum, and to meaningfully contribute to environmental studies, thus deepening their connection with nature. This effect was enhanced where opportunities to engage with project leaders, such as scientists or experts, were available. In the context of citizen science, leaders are likely to be knowledgeable, impassioned, nature-connected professionals, and consequently, excellent role models for influencing nature connectedness. Existing literature identifies some of the significant influences on nature connectedness within environmental programming to include: 1) working and learning with others in community, 2) learning about the interconnectivity of humans with nature, 3) instructional and intentional guidance from role models, and 4) authentic research settings where real contributions can be made (Theimer & Ernst, 2012; Chawla, 1999; Sivek, 2002). These findings are related to various iterations of social learning theory, which proposes that learners observe and model the behaviours, attitudes and emotional reactions of others through a process of reciprocity, self-reflection, and adaptation (Bandura, 1986). Lave and Wenger (1991) defined this as "situated learning", in which learning is an outcome of social participation, rather than the other way around. Social participation in communities of practice results in the construction of identities and behaviours relative to those communities, shaping who we are, what we do, and how we interpret our own behaviour (Muro & Jeffrey, 2006). It follows that the collective, contributory action that takes place within many citizen science projects would have a strengthening effect on participants' nature connectedness. Moreover, many citizen science projects bring awareness to the interconnectivity of all things, an understanding crucial to the development of environmental sensitivity (Fien, 1993 as cited in Lugg & Slattery, 2007). Therefore, consolidation of

the experiences related to these three themes naturally culminates in feelings of unification for participants on many levels.

Wellbeing. Improvements in overall life satisfaction and wellbeing were reported by more than three quarters of the study sample, indicating the potential for citizen science to broadly incur wellbeing benefits. While research on the intersection of citizen science and wellbeing is limited, existing studies support a relationship between wellbeing and participation in conservation efforts, mainly due to the social, active, and contributory aspects of these activities which often take place in natural, outdoor settings (Koss & Kingsley, 2010; Moore, Townsend & Oldroyd, 2006; Birch, 2005). The findings of this study align with previous research, and several previously identified themes emerged from participant views for why citizen science involvement had improved overall life satisfaction. These themes were nature connectedness, collaboration and community building, personal enrichment and growth, and meaningfulness. In a majority of instances, these themes were outcomes of the transformative process that began with strengthened nature connectedness (Figure 3), and were closely linked with the collective learning, contribution and empowerment sub-themes of nature connectedness.

Improvements in overall life satisfaction and wellbeing were described by 90% of respondents who reported increased nature connectedness. Furthermore, increased nature connectedness was explicitly credited with improving wellbeing, lending additional weight to the nature connectedness-wellbeing relationship that is firmly supported by a surfeit of previous research. Numerous studies have identified specific nature-related wellbeing benefits, including subjective increases in personal autonomy, life purpose (Howell, Dopko, Passmore, & Buro, 2011), mood elevations and ability to cope with life stresses, as well as empirical reductions in physical ailments such as blood pressure, depression, and disease (Sandifer et al., 2015). The subjective benefits listed above are confirmed by the findings of this study in addition to improved self-confidence, sense of empowerment, personal achievement, and hope for the future. Amid ample evidence in support of the relationship between nature connectedness and wellbeing in a wide variety of contexts, the association between these two variables predictably showed the strongest relationship among the three (p=.672), indicating the nature connectedness-wellbeing relationship is also present and very strong within the context of citizen science.

In addition to nature connectedness, many of these same wellbeing benefits were outcomes of the social aspects of citizen science activities. Meeting new people and engaging in social interaction over shared interests was widely cited among reasons for gains in wellbeing, as were collaboration and

community building. The link between social interaction and wellbeing is universally accepted; however, focus on this connection within the context of conservation and environmental initiatives is scant, and even more so within the citizen science framework. Existing studies have highlighted the wellbeing benefits of social interaction and bonding that citizen science and conservation activities foster, and the building of community and social capital that these interactions generate. Townsend, Moore and Oldroyd (2006) studied the wellbeing benefits of involvement in conservation groups and found that membership had significant impacts on the health and wellbeing of participants as compared with a control group. The participants of conservation groups reported increased social networks, greater access to personal supports, reduced isolationism, and feelings of belonging as a result of the social and collaborative nature of activities (Townsend et al., 2006) – outcomes consistent with the findings of the present study. Moreover, the conservation groups contributed considerably to the social capital and civic environmentalism of communities, demonstrating the potential for such groups to bring about broad individual and community wellness benefits (Townsend et al., 2006). According to Townsend et al. (2006, p. 111), social capital is "defined in terms of networks, trust and norms which facilitate cooperation and cohesion in communities." When these aspects are present in communities or groups, such as those formed around citizen science projects, they act as resources for individuals to realise their personal goals and development, thus contributing to wellbeing (Pretty & Smith, 2004). This platform could be forming the basis for wellbeing outcomes related to personal enrichment and growth reported in this study, which participants described achieving through the collaborative and social aspects of citizen science activities.

Personal enrichment and growth formed a large component of wellbeing gains in the citizen science context. This theme emerged, in part, from participants' acquisition of new skills and knowledge, and a desire and self-competency to diffuse those skills among others, both achieved during the nature connectedness strengthening process. Likewise, a learned understanding of the interconnectedness of all things, increased nature awareness, and feelings of contribution and unity were mechanisms of increased nature connectedness that also made significant contributions to the enrichment and growth experiences of participants in citizen science, and therefore positively impacted their wellbeing. As a result, participants reported feelings of confidence, pride, enjoyment, hope, inspiration and a greater sense of purpose. Meaningfulness, another major wellbeing theme, was linked primarily to the contributory and collaborative aspects of citizen science activities and led participants to feel they were part of a greater good, as well as a sense of belonging and connection to communities of people, a collective effort, and to "something bigger" than oneself, which compounded the

enriching experience of citizen science participation. These findings are in alignment with Ryff and Singer's (2008, p. 13) definition of psychological wellbeing, expressed as "living a life rich in purpose and meaning, continued growth, and quality ties to others." Although comparative studies that take place within the citizen science context could not be found, similar studies have been conducted to uncover the wellbeing benefits of volunteerism. Increased social capital (Dekker & van den Broek, 1998), social inclusion (Black & Living, 2004), skills development, personal growth, increased self-confidence, and sense of making a contribution (Dalgleish, 2006) are reported outcomes of volunteerism related to personal enrichment and growth. In a study of the wellbeing benefits derived from conservation-based volunteer activities, the authors found that participants derived meaning from their activities, developed confidence, and felt part of a community (O'Brien, Townsend & Ebden, 2010). Given that the citizen science model provides a natural platform for cultivating these wellbeing outcomes, programs should be developed with the intention of fostering them, particularly since this and other studies have found a connection between wellbeing and sustainable behaviour.

Sustainable behaviour. Increased motivation for sustainable behaviour was reported by 70% of the study sample. Approximately 90% of these respondents also reported improved wellbeing and/or strengthened nature connectedness, since people who feel more connected to nature are more likely to have strong conservation values (Arbuthnott et al., 2014; Geng et al., 2015), as well as to both exhibit and self-report more sustainable behaviours (Trostle, 2008; Frantz et al., 2013; Lam & Cheng, 2002). There is also evidence of a reciprocal correlational relationship between wellbeing and sustainable behaviour (Kasser, 2009; Hartig, & Bowler, 2001; Corral-Verdugo et al., 2011; Marks et al., 2006). Scholars examining how conservation interventions and campaigns motivate sustainable behaviours have identified a number of important factors affecting the efficacy of such programs. They suggest that for programs to successfully motivate sustainable behaviour they should be consistent in their messaging, participatory and empowering at the individual level, and holistic in that they address environmental issues at all levels of society as a whole (Lucas et al., 2008). They should also support autonomy, which is related to self-determined, or intrinsically motived, behaviours, and be bottom-up structured (Lavergne et al., 2010). Programs that are perceived to be top-down or controlling can have the opposite of the intended effect, and instead de-motivate sustainable behaviour (Lavergne et al., 2010). While citizen science projects vary considerably by activity, subject matter, and degree of involvement, this and other studies have shown that citizen science projects are generally empowering, pro-autonomy, and holistically address environmental issues by incurring benefits at multiple levels of society. Citizen science projects are also generally perceived as collaborative or collective by design,

each participant's role being equally valued. Therefore, the citizen science framework inherently fosters intrinsically motivated sustainable behaviours, in which participants are inspired rather than coerced to act.

Two major themes underscored responses to why participants felt more motivated to protect nature as a result of their citizen science experience. These were appreciation and inspiration. Appreciation was strongly influenced by the experiential aspects of citizen science activities, and a gain in knowledge about nature. The authenticity of citizen science activities seemed to play a role in how participants understood and integrated the knowledge that all things are interconnected, including themselves with nature. This understanding formed the basis of strengthened nature connectedness, and precipitated a process of reflection on the human-nature relationship, including the ways in which human behaviour impacts natural systems, both positively and negatively. An understanding and appreciation for the interconnectedness of all things forms the basis of nature connectedness, and is critical to intrinsically motivating sustainable behaviour (Davis, Green, & Reed, 2009). Seeing beauty in natural settings and witnessing first-hand the devastating effects that humans have on the environment triggered processes of transformation for many respondents, who reported feeling "changed" by their citizen science experiences. Similarly, citizen science highlighted the positive impacts of human action, especially those amassed when the efforts of many individuals are combined, such as the repopulation of a species in decline, resulting in feelings of individual and collective empowerment.

The influence of others on motivating sustainable behaviour proved equally as powerful in the citizen science context. Inspiration was widely reported among motivated participants, who were influenced by the dedication and persistence of other project members, and by the atmosphere and spirit of the project and group in general. Feelings of overwhelm to face issues on their own were overcome by membership to a group who was facing them collectively. The presence of role models or experts enhanced this effect, and fostered a spirit of kinship and competence among like-minded individuals. Participants felt a sense of belonging to communities of practice, influencing and being influenced by others to protect nature and help solve environmental problems.

These findings are backed by existing research, which demonstrates that environmental awareness and knowledge contribute to increased motivation for sustainable action (Mittelstaedt et al., 1999; Dresner & Gill, 1994). Also, appreciation and inspiration through collective action play a valuable role in motivating sustainable behaviours within the context of conservation initiatives (Evans et al., 2005). Campers of a week-long experiential education program attributed increased awareness

and appreciation of nature to the meaningful experiences they had in nature, which led to increased nature connectedness and motivation for sustainable behaviour (Mittelstaedt et al., 1999). Nature appreciation is a precursor to both nature connectedness and sustainable behaviour, and is effectively cultivated in experiential environmental education programs that take place in natural settings with others (Somwaru, 2016).

Furthermore, the social value of citizen science cannot be understated. Citizen science projects have the opportunity to build social communities that are empowering, which significantly impacts participants' learning experiences and perceptions of competence to achieve project goals (Price & Lee, 2013). Social learning assists the spread of new ideas more rapidly, and the development of new social norms and institutions, including sustainable behaviour (Pretty & Smith, 2004). Social learning also lends itself to opportunities for individuals to inspire and be inspired by others, engendering transformations of thought, behaviour, and identity, as this study has demonstrated. Bandura (1997) contends that the scale of environmental problems is disempowering at the individual level, but that unified groups with shared goals can be transformative by acquiring a collective sense of competence. Social cohesion is associated with increased empowerment, and should be considered in the effort to motivate sustainable behaviour in the context of citizen science (Speer, Jackson, & Peterson, 2001). There is growing evidence for the development of conservation interventions and activities that create social networks and groups, and which seek and incorporate the knowledge of participants in the development and implementation phases, to motivate long-term environmental protection (Singh & Ballabh 1997; Krishna 2002; McNeely & Scherr, 2003 as cited in Pretty & Smith, 2004). Such groups are beginning to be recognized for their effectiveness in bringing about positive environmental outcomes (Pretty & Smith, 2004).

Lessons Learned

Nature connectedness, wellbeing and sustainable behaviour are worth nurturing. The presence of a strong relationship between nature connectedness, wellbeing and sustainable behaviour among citizen science participants highlights an opportunity for environmental practitioners to give greater consideration to designing campaigns and projects that foster these constructs to promote sustainable behaviour. This study demonstrates that citizen science projects are already successfully producing these outcomes. Greater intention to embed key elements that enhance these constructs within the citizen science experience could improve the efficacy of projects, and potentially incur broad environmental and social benefits, including greater motivation for environmental action,

increased social cohesion around environmental issues and capacity to identify and address problems, and improved individual and social wellbeing.

A social approach to conservation interventions. Ehrlich, Kareiva and Daily (2012), along with others, have recognized the need for a paradigm shift in the way conservation interventions approach environmental education and attempt to motivate behaviour change. That is, focus needs to shift away from the linear model that assumes knowledge leads to action, and toward a holistic approach that recognizes the social and cultural complexities affecting behaviour. For decades, environmental education programs have been moving their classrooms outdoors in an effort to "…provide opportunities that encourage enjoyment, appreciation and awareness of the environment" (Palmer, 1998, p. 28). This is exemplary of a "practical – interpretive" paradigm (Palmer, 1998, p. 28), and has been criticized on the grounds that it promotes learning *in* and *about* the environment (Lugg & Slattery, 2003) rather than *for* or *with* the environment, as proposed by Gough (as cited in Palmer, 1998). Räthzel & Uzzell (2009, p. 271) share this criticism, and propose that the goal of programs should be to "encourage people to formulate and understand in more comprehensive ways what they know through their experience in the everyday, thereby revealing the structural relations and ways in which we are all part of reproducing these relations through our daily practices." They argue for a democratization of the effort to address sustainability issues, in which people are engaged not only in the realizing of goals but in the formulating of them, and call for a change in the existing relations between teacher and learner that reinforce power dynamics, toward one in which the learner is an equitable player in the change-making process (Räthzel & Uzzell, 2009). Indeed, citizen science is already challenging the status quo by inherently addressing these calls for change to the traditional model, earning its merit as an innovative and transformative conservation intervention. Aptly dubbed "community science" (Bear, 2016), "community research" (Theobald et al., 2015), and "community-based monitoring" (Conrad & Hilchey, 2011), citizen science projects invite volunteers to work in partnership with trained experts, local agencies, and community members to identify, design and carry out conservation research and activities, and makes meaningful contributions to science, conservation policy, and the environment. The results of this study show that citizen science also provides significant social and individual benefits, positively impacting the wellbeing of participants, fostering social cohesion among communities and groups, and motivating sustainable behaviour through a transformative process of personal change.

The findings of the present study make a strong case for the design of conservation interventions that mimic the features of citizen science projects to produce these same social and

environmental benefits. Since citizen science was designed to expand the data collection capacity of scientists and reduce research costs, however, these benefits are more of a pleasant by-product than the results of intentional design. While this does not devalue them in any way, it does leave one wondering whether a more purposeful approach, one in which experts from the social disciplines are included at the outset, could inform a more effective and deliberate model for influencing sustainable behaviour. This study has identified just some of the pathways and influencing factors that lead participants of citizen science to feel more deeply connected to nature, to experience greater overall wellbeing, and to be more motivated to act in sustainable ways. By developing projects and interventions that are informed by the model of personal transformation presented here (Figure 5), and which incorporate into their design some or all of the influencing elements that would lead participants through this transformative process, outcomes could potentially be dramatically improved. Based on this model, some suggestions for program coordinators and developers include fostering a spirit of social bonding and communities of practice, putting greater emphasis on the real-world impacts and implications of participation in citizen science activities and the contributions made through involvement, and providing for opportunities to interact with and reflect upon nature. At a time when many are seeking alternate or new ways to escape the stresses of daily life, to make meaningful contributions, and to develop themselves personally, citizen science as a leisure activity holds significant potential to address these, and numerous other, personal and social needs.

For decades, scholars have been pushing for an interdisciplinary approach to conservation efforts in opposition to the pure sciences method that has dominated (Zylstra et al., 2014; Daily & Ehrlich, 1999). As Balmford and Cowling (2006, p. 692) point out, “Conservation is primarily not about biology but about the people and the choices they make.” In order to move beyond a model of participatory interventions that incidentally motivate sustainable behaviour, collaboration between the natural and social sciences sectors will be required to design programs that intentionally address the underlying social causes of environmental destruction and transform not only participating individuals, but the social conditions within which they live. Such a re-organizing demands that natural scientists, those usually at the helm of conservation efforts, first undergo their own transformative processes to acknowledge that environmental problems are rooted in social and cultural trends. This study uncovered some of the complex mechanisms by which citizen science influences motivation for sustainable behavior (Figure 5), such as through increasing nature connectedness and by fostering communities of practice. In doing so, it has provided further evidence in support of the argument that

environmental issues are social issues, and a more social and interdisciplinary approach is required to address the conservation dilemma.

Limitations

Study design was limited by cost, time and practicality, resulting in a non-experimental research design. Therefore, a non-causal, correlational enquiry only could be achieved, rendering this an exploratory study. These same reasons necessitated the use of non-probability sampling techniques for recruiting participants, hence the findings of this study are not generalizable to the overall population of citizen scientists. An attempt to compare the demographic sample of this study with others fell short as no other general study of the citizen scientist population could be found. The sampling methods used were convenience and snowball, since citizen scientists are identifiable only through the projects and groups they identify with. These techniques may introduce bias, as participants are referred by others in their networks and self-selected to participate. Nonetheless, since this is a relatively new area of research, and to the author's knowledge no inquiry of its kind has ever been conducted within the context of citizen science, this study provides a valuable framework to build future research upon, and the findings validate the need for more investigation into this area.

Several statistical and data limitations were present. To capture a wide range of citizen science traits and experiences, a large sample size was amassed. For practical reasons, this necessitated the use of a survey research strategy. Self-administered, online surveys accentuate the need for high-quality, comprehensive questionnaires since respondents have no access to assistance. Therefore, we cannot overlook the possibility that some responses were less accurate than they may have been had communication to assure understanding been possible. Large sample sizes also befit the collection of predominately quantitative data, which limits the type and quality of data that can be acquired.

For some questions about citizen science traits, an "other" field was provided where participants could answer in their own words. For example: W*hat kind of citizen science project is it? What type of activities are you involved in when you're participating?* And *Please describe what you do in your citizen science project?* The open-ended responses from these questions were qualitatively analysed to create new response categories, along with the multiple-choice options available. For each question, the number of response categories resulting from this process became too numerous to allow for meaningful statistical analysis, since the assumption of adequate cell count was violated in every case. Therefore, no meaningful information was able to be derived from this data. Where possible, this data was used to identify other correlational relationships instead. For example, it was not possible to identify which *types of activities* most strongly correlate with increases in the self-report variables

because most respondents were participants in more than one activity, resulting in 67 unique combinations of activities in which respondents were participants of between one and ten. Instead, these data were used to identify a statistically significant, positive association between number of activities involved in, and self-reported increases in nature connectedness, wellbeing and motivation for sustainable behaviour.

Directions for Future Research

This study validates the need for future inquiry into the intersection of nature connectedness, wellbeing, and sustainable behaviour within the context of conservation interventions. The findings suggest that citizen science is a model worthy of investigative research into the mechanisms for increasing motivation for sustainable behaviour through nature connectedness and wellbeing. Studies aimed at learning more about how these processes take place could help identify ways to intentionally cultivate these outcomes within citizen science projects, and inform more effective intervention models. Targeted studies aimed at identifying the antecedents to nature connectedness, wellbeing and sustainable behaviour within the context of citizen science are required. Under what conditions are these constructs nurtured? Are there factors that curtail these outcomes? What types of people are attracted to citizen science activities and does this impact upon how they respond to citizen science exposure with respect to nature connectedness, wellbeing and sustainable behaviour? What citizen science typologies or traits are most conducive to nurturing these constructs?

Although the qualitative findings did not show that respondents made an explicit link between wellbeing and sustainable behaviour, the wellbeing outcomes reported were found to have influenced upon participant's motivation for sustainable behaviour. For example, respondents reported feeling a greater sense of belonging to a community of practice, which motivated them to reflect the values of that community and be more sustainable. Given that the relationship between wellbeing and sustainable behaviour has been identified previously (Corra-Verdugo et al., 2011), as has the connection between social environments of learning and practice with sustainable behaviour motivation (Evans et al., 2005), more focus on this relationship is warranted.

With the breadth of positive social and environmental outcomes incurred by citizen science at multiple levels of society, as reported by the study sample and supported by previous research (ie. increased personal wellbeing, community cohesion, and support for agencies and organizations), improving our understanding of what conditions nurture these outcomes is a worthwhile pursuit (Koss & Kingsley, 2010; Moore, Townsend, & Oldroyd, 2006; Bliss et al., 2001). By demonstrating the presence of the nature connectedness – wellbeing – sustainable behaviour framework within the citizen

science model, and presenting a process of personal transformation occurring due to citizen science exposure, it is my hope that other researchers will see the social and environmental value in continuing this line of research.

Summary

New, innovative, and more effective methods are required to address the underlying socio-psychological causes of environmental degradation. Literature has identified strong, positive relationships between nature connectedness, wellbeing and sustainable behaviour that may play a key role in influencing sustainable behaviour change. This study has shown that these relationships exist within the citizen science model, and that participants of citizen science activities undergo personal transformative processes that strengthen their connections with nature, improve their wellbeing, and increase their motivation for sustainable behaviour. Furthermore, participants who are deeply involved in citizen science activities for longer periods of time more frequently report increases in these constructs. Citizen science provides a valuable model for studying the mechanisms of sustainable behaviour motivation using this framework; however, more research is required to learn how to effectively capitalize on these relationships to address large-scale, anthropogenic environmental issues.

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APPENDIX A: 6-Item Nature Relatedness Scale

SHORT FORM VERSION OF THE NATURE RELATEDNESS SCALE (NR-6) Instructions:

For each of the following, please rate the extent to which you agree with each statement, using the scale from 1 to 5 as shown below. Please respond as you really feel, rather than how you think “most people” feel.

1	2	3	4	5
Disagree Strongly	Disagree a Little	Neither agree Or disagree	Agree a Little	Agree strongly

1. My ideal vacation spot would be a remote, wilderness area.
2. I always think about how my actions affect the environment.
3. My connection to nature and the environment is a part of my spirituality.
4. I take notice of wildlife wherever I am.
5. My relationship to nature is an important part of who I am.
6. I feel very connected to all living things and the earth.

APPENDIX B: Personal Wellbeing Index - Adult

Instructions for Written Format (i.e. test items answered in written questionnaire)

The following questions ask how satisfied you feel, on a scale from zero to 10. Zero means you feel no satisfaction at all and 10 means you feel completely satisfied.

1. "How satisfied are you **with your standard of living ?"**

No satisfaction at all										Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

2. "How satisfied are you **with your health ?"**

No satisfaction at all										Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

3. "How satisfied are you **with what you are achieving in life ?"**

No satisfaction at all										Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

4. "How satisfied are you **with your personal relationships ?"**

No satisfaction at all										Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

5. "How satisfied are you **with how safe you feel ?"**

No satisfaction at all										Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

6. "How satisfied are you **with feeling part of your community ?"**

No satisfaction at all										Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

7. "How satisfied are you **with your future security ?"**

No satisfaction at all										Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

8. "How satisfied are you **with your spirituality or religion ?"**

No satisfaction at all										Completely Satisfied
0	1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

APPENDIX C: Motivation for Environmental Action Scale

Please indicate how much you **DISAGREE** or **AGREE** with each of the following statements by placing an **X** in the appropriate column. Please respond as you really feel, rather than how you think "most people" feel.

Think about some of the things you do to protect nature or help solve environmental problems. Why do you do these things?	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. Because I think it's a good idea to do something for the environment	1	2	3	4	5
2. Because other people will be disappointed in me if I don't	1	2	3	4	5
3. Because I'm concerned about what could happen to people I care about if I don't do anything	1	2	3	4	5
4. Because I would feel guilty if I didn't do anything for the environment	1	2	3	4	5
5. Because I enjoy doing it	1	2	3	4	5
6. Because I'm concerned about what could happen to me if I don't do anything	1	2	3	4	5
7. For the pleasure I experience while doing it	1	2	3	4	5
8. Because people I look up to think it's a really good thing to do	1	2	3	4	5
9. Because I think it's a good idea to protect nature	1	2	3	4	5
10. Because it's fun to do it	1	2	3	4	5
11. For the recognition I get from others	1	2	3	4	5
12. Because I think it's important to take care of the environment	1	2	3	4	5
13. Because I'm concerned about what could happen to the natural world if I don't do anything	1	2	3	4	5
14. Because I want people to see me as a good person	1	2	3	4	5

APPENDIX D: Questionnaire

NATURE RELATEDNESS					
Please respond as you really feel, rather than how you think "most people" feel.	Disagree Strongly	Disagree a little	Neither agree nor disagree	Agree a little	Agree Strongly
1. My ideal vacation spot would be a remote wilderness area	1	2	3	4	5
2. I always think about how my actions affect the environment	1	2	3	4	5
3. My connection to nature and the environment is a part of my spirituality	1	2	3	4	5
4. I take notice of wildlife wherever I am	1	2	3	4	5
5. My relationship to nature is an important part of who I am	1	2	3	4	5
6. I feel very connected to all living things and the Earth	1	2	3	4	5

PERSONAL WELLBEING
The following questions ask how satisfied you feel, on a scale from zero to 10. Zero means you feel no satisfaction at all and 10 means you feel completely satisfied.
1. How satisfied are you **with your standard of living?**
2. How satisfied are you **with your health?**
3. How satisfied are you **with what you are achieving in life?**
4. How satisfied are you **with your personal relationships?**
5. How satisfied are you **with how safe you feel?**
6. How satisfied are you **with feeling part of your community?**
7. How satisfied are you **with your future security?**
8. How satisfied are you **with your spirituality or religion?**

MOTIVATION FOR ENVIRONMENTAL ACTION					
Think about some of the things you do to protect nature or help solve environmental problems. Why do you do these things?	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. Because I think it's a good idea to do something for the environment	1	2	3	4	5
2. Because other people will be disappointed in me if I don't	1	2	3	4	5
3. Because I'm concerned about what could happen to people I care about if I don't do anything	1	2	3	4	5

4. Because I would feel guilty if I didn't do anything for the environment	1	2	3	4	5
5. Because I enjoy doing it	1	2	3	4	5
6. Because I'm concerned about what could happen to me if I don't do anything	1	2	3	4	5
7. For the pleasure I experience while doing it	1	2	3	4	5
8. Because people I look up to think it's a really good thing to do	1	2	3	4	5
9. Because I think it's a good idea to protect nature	1	2	3	4	5
10. Because it's fun to do it	1	2	3	4	5
11. For the recognition I get from others	1	2	3	4	5
12. Because I think it's important to take care of the environment	1	2	3	4	5
13. Because I'm concerned about what could happen to the natural world if I don't do anything	1	2	3	4	5
14. Because I want people to see me as a good person	1	2	3	4	5

CITIZEN SCIENCE INFORMATION

1. ACTIVE: Are you actively involved in a citizen science activity at present?

O Yes O No

2. INACTIVE: How long has it been since you were active in a citizen science activity?

O < 1 week O < 1 month O 1-3 months

O 3-6 months O 6-9 months O > 9 months

3. LENGTH OF PARTICIPATION: How long have you been/were you participating in citizen science activities?

O < 1 week O < 1 month O 1-3 months

O 3-6 months O 6-9 months O > 9 months

4. PROJECT: What citizen science project are/were you involved in?

Name of program: _____

Name of organization: _____

Name of coordinator: _____

5. TIME COMMITMENT: Roughly how many hours per week do/did you participate in a citizen science project?

O 0-2 O 3-5

O 6-8 O > 9

6. ACTIVITY TYPE: What type of activities are/were you involved in when doing citizen science? (check all that apply)

Please describe what you do while participating in citizen science activities. Be specific. (ie: physical data collection, data entry, mapping, monitoring, etc.)

_____

7. PERSONAL WELLBEING: Do you feel an increased sense of personal wellbeing because of your participation in citizen science?

O Yes O No O Not sure/maybe

O If yes, what is it about participating that has made you feel an increased sense of wellbeing?

_____

8. NATURE CONNECTEDNESS: Do you feel more closely connected to nature because of your participation in citizen science?

O Yes O No O Not sure/maybe

If yes, what is it about participating that has made you feel more connected to nature?

_____

9. MOTIVATION FOR SUSTAINABLE BEHAVIOUR: Do you feel more motivated to be behave sustainably or be environmentally active because of your participation in citizen science?

O Yes O No O Not sure/maybe

If yes, what is it about participating that has made you feel more motivated?

_____

APPENDIX E: Informed Consent

" Examining nature connectedness, wellbeing and motivation for sustainable behaviour in the context of citizen science "

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Nicole Vaugeois, Ph.D., Supervisor
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This research is part of my Master's thesis, which is a partial fulfilment of my MA Degree in Sustainable Leisure Management at Vancouver Island University, British Columbia, Canada. The purpose of this study is to find out if and how citizen science programs increase participant's feelings of nature connectedness, wellbeing and motivation for sustainable behaviour. During this questionnaire, you will be asked to complete a number of questions concerning your feelings of connection to nature, wellbeing and motivation for sustainable behaviour. Socio-demographics questions, including gender, age range and country of residence will be asked, however, the survey does not contain any information that will personally identify you. Interviewees will remain completely anonymous. Your participation will require approximately 10 minutes of your time.

There are no harms associated with your participation in this research. The potential benefits of this study are that it will help citizen science program developers more effectively design programs that connect citizen science participants with nature, improve their wellbeing, and foster increased motivation for sustainable behaviours.

This survey is hosted by a web-survey company called *Google Forms.* This company is located in the USA and as such is subject to U.S. laws. In particular, the US Patriot Act which allows authorities access to the records of Internet service providers. However, this survey does not ask for any information that may be used to identify you. Therefore, you will remain completely anonymous and no link can be made between you and the data. I do not collect any identifying information such as IP address or web-site cookies. Your confidentiality will be maintained to the degree permitted by the technology used. Specifically, for data sent via the Internet, no guarantees can be made regarding the interception of data by any third parties. Here is a link to the survey website's privacy policy for more information regarding the privacy of Google Forms: https://support.google.com/docs/answer/148505?hl=en&ref_topic=1360897

All records of participation will be kept strictly confidential, such that only my supervisor and I will have access to the information. Electronic files will be stored on a password-protected computer. All data will be destroyed by deletion at the end of the project, approximately April 2017. The results from this study will be reported in a written thesis report and an oral presentation at my thesis defense. Information about the project will not be made public in any way that identifies individual participants.

Your participation is completely voluntary. You may withdraw at any time for any reason without explanation and without penalty. You may choose not to answer any question for any reason. Due

to the anonymous nature of this survey, no survey data will be identifiable with any particular participants. If you have any concerns about your treatment as a research participant in this study, please contact the VIU Research Ethics Officer, by telephone at 250-740-6631 (or toll free at 1-888-920-2221, extension 6631) or by email at reb@viu.ca.

If you have any questions about this research project, or would like more information, please feel free to contact me, Michelle Harnett, at this e-mail address: michelle.harnett@stumail.viu.ca

By completing and submitting this online survey, you are consenting to participate in this research and for information you provide to be used in study results.