Citizen Science as a Tool for Monitoring Intermittent Streams in Colorado, USA

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Abstract

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Intermittent streams are in need of increased attention and research because they are understudied despite being among the most widely distributed and dynamic freshwater ecosystems on Earth. Citizen science has the potential to greatly improve knowledge on intermittent streams and is an attractive alternative to standard stream monitoring methods. The purpose of this research is to provide project managers with information on how to design socially and scientifically successful projects that fulfil their potential to enhance understanding of intermittent streams. Online surveys and interviews were used to research citizens' motivations to monitor streams and scientists' perceptions of citizen science. Data quality checks were used to investigate the ability of citizen scientists to collect high quality data. The most important motivators were location of streams, wanting to contribute to research and having a pre-existing interest in water. Scientists surveyed indicated a mostly positive perception of citizen science. A case study on the project Stream Tracker revealed citizen scientists' ability to collect high quality data on streamflow. Results can be used by project managers to improve recruitment and retention of participants and to design scientifically rigorous projects that will produce high quality data and be well received by the scientific community.

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Table of Contents

List of Figures **5**

List of Tables **6**

Chapter 1: Introduction **7**
1.1 Purpose 7
1.2 Aims and Objectives 7
1.3 Study Location 8
1.4 Overview 10

Chapter 2: Literature Review **11**
2.1 Citizen Science 11
2.2 Intermittent Streams 12
2.3 The Potential of Citizen Science for Monitoring Streamflow 12

Chapter 3: Citizens' Interest and Motivations **14**
3.1 Introduction 14
3.2 Literature Review 14
3.3 Methods 21
3.4 Results and Discussion 22
3.5 Conclusion 32

Chapter 4: Scientists' Perceptions **33**
4.1 Introduction 33
4.2 Literature Review 33
4.3 Methods 35
4.4 Results and Discussion 36
4.5 Conclusion 44

Chapter 5: Stream Tracker Case Study **45**
5.1 Introduction 45
5.2 Background 45
5.3 Methods 49
5.4 Results and Discussion 50
5.5 Conclusion 56

Chapter 6: Conclusion **57**
6.1 Key Findings 57
6.2 Limitations 57
6.3 Future Research 58

References **60**

Appendix **69**

List of Figures

Figure 1.1. Study site location – Colorado, USA.. 9
Figure 3.1. Frequency of responses for each motivation in order of strongest to weakest agreement. 18
Figure 3.2. Frequency of responses for each statement about social interactions in order of strongest to weakest agreement. 19
Figure 3.3. Age distribution of respondents to survey 1. 23
Figure 3.4. Gender distribution of respondents to survey 1. 23
Figure 3.5. Employment status of respondents to survey 1.................................24
Figure 3.6. Education level of respondents to survey 1......................................24
Figure 3.7a. Citizen' level of interest in monitoring intermittent streams in three scenarios. 26
Figure 3.7b. Change in interest from initial interest for three scenarios..............27
Figure 4.1. Age distribution of respondents to survey 2. 37
Figure 4.2. Gender distribution of respondents to survey 2. 37
Figure 4.3. Education level of respondents to survey 2......................................38
Figure 4.4. Responses from survey 2 about whether citizen scientists can collect data that is of comparable quality to data collected by professional scientists......39
Figure 4.5. Responses from survey 2 about whether citizen science data can be used to publish papers. 39
Figure 4.6. Scientists' level of agreement with three statements about citizen science. 41
Figure 5.1. Stream Tracker Project logo..45
Figure 5.2. Photos taken by Stream Tracker participants showing flow (A) and no flow (B) 46
Figure 5.3. Maps.me logo...47
Figure 5.4. CitSci.org logo..47
Figure 5.5. Stream Tracker diagram explaining how to start stream tracking......48
Figure 5.6. How respondents to survey 3 rated their experience of participating in Stream Tracker...51
Figure 5.7. How likely respondents to survey 3 are to participate in Stream Tracker again. 52
Figure 5.8. How far into the future respondents to survey 3 would participate in Stream Tracker...52
Figure 5.9. How respondents to survey 3 rated their experience of using the maps.me and CitSci.org apps..53
Figure 5.10. How useful respondents to survey 3 think a Stream Tracker app would be. 54
Figure 5.11. Proportion of correct and questionable Stream Tracker observation from citizen scientists after photo validation...56

Note: First number of figure corresponds to chapter number.

List of Tables

Table 3.1. Motivations to volunteer for The Nature Conservancy.......................15
Table 3.2. Motivations for participation in three environmental stewardship projects. 16
Table 3.3. Save Our Streams volunteers' importance ratings for motivation factors for water quality monitoring..17
Table 4.1. Responses of scientists when asked how they think the wider scientific community perceives citizen science. 42

Note: First number of table corresponds to chapter number.

Chapter 1: Introduction

Intermittent streams require increased attention because they are understudied despite being among the most abundant, widely distributed and dynamic freshwater ecosystems on Earth (Nadeau and Rains, 2007; Datry *et al.,* 2014; Poff, 1996; Williams, 1996; Larned *et al.,* 2010). Engaging citizen scientists in monitoring the streamflow of intermittent streams has the potential to provide data of much higher spatial and temporal resolution compared to standard methods and can help create useful datasets that would not be possible by scientists alone (Turner and Richter, 2011; Lowry and Fienen, 2012). The acute scarcity of streamflow data on intermittent streams and the potential citizen scientists have for filling this data gap means it is pertinent to explore citizen science as a tool for monitoring intermittent streamflow.

This chapter will firstly define and defend the purpose of this dissertation before introducing the study aims and objectives. This is followed by a description of the study location. Finally, an overview of the content of this dissertation is provided.

1.1 Purpose

To gain a deeper understanding of citizen science as a tool for monitoring intermittent streams. To provide information that will help project managers design socially and scientifically successful citizen science projects that fulfil their potential to improve our understanding of intermittent streams.

1.2 Aims and Objectives

This dissertation aims to answers three research questions (objectives are listed under each).

Research question 1: What interests and motivates citizens to monitor intermittent streams?

a. Survey citizens on what would motivate them to participate in a citizen science project to monitor intermittent streams.
b. Investigate the experiences of participants involved in a current citizen science project monitoring intermittent streams.

Research question 2: How do scientists perceive citizen science as a tool for monitoring intermittent streams?

a. Investigate how scientists might receive data collected by citizen scientists on intermittent streams.
b. Identify any areas of citizen science that need specific attention in order for scientists to be accepting of citizen science data on intermittent streams.
c. Investigate the experience of current project managers.

Research question 3: How useful is citizen science for producing high quality flow data on intermittent streams?

a. Analyse photos uploaded to CitSci.org by citizen scientists.
b. Verify if observations by citizen scientists were correct through photo validation.

1.3 Study Location

The study was conducted in Colorado, USA as a result of working closely with a citizen science project based at Colorado State University (CSU) (case study in Chapter 5).

Colorado is a western state in the USA (Figure 1.1). The state has some of the highest mountains of the Continental Divide with an average altitude of 6,800 feet above sea level (Doeskan *et al.,* 2003). The high elevation and mid latitude interior continent location (distant from major sources of moisture) gives this state a cool, dry climate (Doeskan *et al.,* 2003). Known as a 'headwater state', Colorado is a particularly interesting location to study intermittent streams because all its rivers (except the Green River) as well as four of the Nation's major rivers (the Colorado, the Rio Grande, the Arkansas and the Platte) have their source within its borders (Doeskan *et al.,* 2003).

Spatial scaling problems due to strong climatic gradients and complex topography has meant knowledge of hydrological feedbacks and the processes controlling them in the western mountains has been limited (Bales *et al.,* 2006). Colorado's extreme weather changes, large seasonal temperature swings and vast ranges in elevation (lowest: 3,315 feet; highest: 14,433 feet) (Doeskan *et al.,* 2003) makes it a location where stream tracking is adventurous and exciting.

Figure 1.1. Study site location – Colorado, USA. Red box: location of Colorado on map of the USA. (Google Maps, no date).

Western USA is experiencing population growth and land cover change on top of the effects of climate change and having a highly variable climate. Countless stakeholders including public agencies, private companies, watershed councils and nongovernmental organisations (NGOs) are in need of better hydrological information in order to make informed, water-sensitive decisions (Bales *et al.,* 2006).

1.4 Overview

Structurally, this dissertation is divided into five chapters. Chapter 1 provides an introduction which details the purpose, aims and objectives of the dissertation and a description of the study location. Chapter 2 consists of a short introductory literature review. Chapter 3 responds to research question 1 and consists of a focused literature review, methods, results, discussion and conclusion. Chapter 4 responds to research question 2 and also consists of a focused literature review, methods, results, discussion and conclusion. Chapter 5 provides a case study of a citizen science project, Stream Tracker, and responds to research questions 1 and 3. Finally, Chapter 6 summarises key findings, acknowledges limitations and suggests directions for future research.

Chapter 2: Literature Review

This chapter is an introductory literature review. Chapters 3 and 4 provide their own detailed and focused literature reviews. Firstly, this chapter reviews the concept of citizen science in the literature (section 2.1). Secondly, a background into the importance of intermittent streams and the gap in streamflow data is provided (section 2.2). Thirdly, the potential of citizen science for monitoring streamflow is reviewed (section 2.3).

2.1 Citizen Science

The term 'citizen science' first appeared in 1995 as the name of a book by Alan Irwin (Irwin, 1995). For Irwin, citizen science was about a movement to democratise science, to consider an active "scientific citizenship" and to engage citizens in science policy (Bonney *et al.,* 2015). However, the concept of citizen science that is now readily adopted by authors is "members of the public partnering with professional scientists to collectively gather, submit or analyse large quantities of data" (Bonney *et al.,* 2015) (although individual authors have their own variations of this definition). The Cornell Lab of Ornithology was the first to use the term in this way, also in 1995, as an alternative term for public participation in scientific research (PPSR). PPSR, crowdsourced science, volunteer monitoring, citizen contributed geographic information (CCGI), volunteer geographic information (VGI), community science and community-based monitoring (See *et al.*, 2016; Shirk *et al.,* 2012) are all examples of terms used in the literature that encompass the field of projects belonging to citizen science. However, it is the term 'citizen science' that is now widely recognised and accepted in the scientific community.

The recent phenomenon of citizen science over the last two decades has been driven by significant technological advances (Cohn, 2008; See *et al.,* 2016). Citizen science now exploits the Internet to combine observations of hundreds of thousands of citizen scientists. This has opened up new pathways allowing for immediate engagement and efficient data collection and visualisation (Catlin-Groves, 2012; Dickinson and Bonney, 2012; Raddick *et al.,* 2010).

2.2 Intermittent Streams

Water provision is one of the most fundamental ecosystem services for humanity and has weighty societal relevance (Buytaert *et al.,* 2014). Decision making on water resources and flood and drought risk assessment is underpinned by hydrological science, yet this area of science is characterised by a severe scarcity of both spatial and temporal data (Hannah *et al*., 2011).

Intermittent streams are of particular importance because they are among the most abundant, widely distributed and dynamic freshwater ecosystems on Earth (Larned *et al.,* 2010; Poff, 1996; Williams, 1996) but research into them has a short history. Despite making up 50-70% of stream networks globally, their dynamics are still largely unknown (Datry *et al.,* 2014; Nadeau and Rains, 2007). Recently, research into intermittent streams has increased (Datry *et al*., 2014) and their importance for water supply, habitat, biodiversity, downstream ecosystems and water quality has been highlighted (Acuña *et al.,* 2014; Acuña and Tockner, 2010; Bernal *et al*., 2013; Bishop *et al.,* 2008; Freeman *et al.,* 2007; Larned *et al.,* 2010; Leigh and Datry, 2016). However, streamflow monitoring is mainly concerned with perennially flowing streams and in most of the world few products are available to map the spatiotemporal extent of intermittent streams. Stream network dynamics have received little attention (Godsey and Kirchner, 2014) and there is a scarcity in streamflow data (Gallart *et al.,* 2016).

Studies have repeatedly found that intermittent streams are either missed or misclassified in map products (Caruso, 2011; Caruso, 2014; Fritz *et al*., 2008; Fritz *et al*., 2006; Hansen, 2001). A substantial advance in knowledge of intermittent streams is needed to contribute to drought research, runoff forecasting, to improve stream protection design and help prevent impacts on water quality and aquatic habitat (Hansen, 2001). Additional monitoring methods are needed because existing maps cannot be used to reliably examine controls on streamflow intermittence.

2.3 The Potential of Citizen Science for Monitoring Streamflow

Citizen science is an attractive alternative to standard methods of monitoring streams for several reasons. Firstly, citizen science has the potential for a broader impact by providing higher spatial and temporal resolution data (Lowry and Fienen,

2012; Turner and Richter, 2011). Secondly, replacing standard methods with citizen science has financial benefits (Turner and Richter, 2011). Thirdly, the utility of aerial photography is limited because of riparian tree canopy covering the view of streams (Turner and Richter, 2011). This limitation is not shared by citizen science which has the potential to collect data in remote areas where hikers may be the only means of data collection (Buytaert *et al*., 2014; Lowry and Fienen, 2012).
Furthermore, studies have shown that citizen science data has the potential to create useful streamflow datasets (Lowry and Fienen, 2012; Turner and Richter, 2011). Successful studies have recommended citizen science for filling in basic hydrological networks and for basins that lack adequate streamflow data or to compliment standard stream gauges (Lowry and Fienen, 2012; Turner and Rickter, 2011). Wet/dry mapping of the San Pedro River by citizen scientists has resulted in the creation of useful maps and a dataset which is having a positive impact by contributing to the design of a new regional recharge effort which replenishes aquifers and supports river flows by collecting local water sources and replacing it back into the ground (Nature.org, 2017).

The next two chapters have detailed literature reviews on citizens' motivations (chapter 3) and scientists' perception of citizen science (chapter 4).

Chapter 3: Citizens' Interest and Motivations

3.1 Introduction

Chapter 3 responds to research question 1; what interests and motivates citizens to monitor intermittent streams? This chapter reviews the literature (section 3.2), describes the methods used (section 3.3), presents and discusses results (section 3.4) and ends with a conclusion (section 3.5).

3.2 Literature Review

Recruitment and retention is often one of the most expensive and time-consuming parts of a project (Conrad and Hilchey, 2011; Heidrich, 1990). Understanding the motivations of citizens enables project managers to increase participation and improve recruitment and retention (Jacobson *et al*., 2012; Raddick *et al.,* 2010; Shirk *et al*., 2012). There is not an awareness of any literature relating specifically to citizen scientists' motivations to participate in monitoring streams. However, several studies have investigated volunteer motivations to participate in nature-based projects (some include stream/river monitoring) which will shed light on this discussion.

The first study to evaluate what motivates people to volunteer for an environmental organisation was by King and Lynch (1998). The authors identified three categories of volunteer motivations – altruistic (aim to help others), social (seek engagement with others) and egoistic (aim to increase personal skills or self-esteem). The study results showed that the most frequent motivation chosen by respondents was altruistic: to do something for nature (Table 3.1). Ryan *et al*. (2001) grouped motivations into five categories (see Table 3.2) and also found that helping the environment was the top motivator. Furthermore, this was found to be the top motivation in two stream monitoring projects (Alender 2016; Roggenbuck, 2001) (Table 3.3 and Figure 3.1) as well as a range of other projects (Asah and Blahna, 2012; Bruyere and Rappe, 2007; Grese *et al*., 2000; Guiney and Oberhauser, 2009; Jacobson *et al*., 2012; Still and Gerhold, 1997).

Table 3.1. Motivations to volunteer for The Nature Conservancy.

Reason	Motive	Number of respondents out of 86 who marked this response.*
To do something for nature	Altruistic	82
To allow the organization to provide more goods/services for less money	Altruistic	40
To learn new skills	Egoistic	36
To stay active	Social	35
To help create a better society	Altruistic	34
Makes me feel better about myself	Egoistic	32
To develop social contacts	Social	30
To feel useful	Egoistic	30
To make friends	Social	26
To explore career options	Egoistic	22
To change social injustices	Altruistic	12
Because of the prestige of the organization	Egoistic	9

*Each reason (motive) could have a possible value of 86 because respondents were permitted to mark multiple reasons for volunteering.

Source: King and Lynch, 1998

Table 3.2. Motivations for participation in three environmental stewardship projects.

	Cronbach α	Mean	Standard deviation
Helping the environment	0.79	4.09[a]	1.02
Seeing improvements to the environment			
Helping to restore natural areas			
Learning	0.77	3.98[a]	0.89
Nature observation			
Learning about specific plants/animals			
Learning new things			
Project organization	0.75	3.26[b]	0.92
Projects are well organized			
Feeling needed			
Knowing what is expected of me			
Working with a good leader			
Social	0.79	3.14[b,c]	0.95
Seeing familiar faces			
Meeting new people			
Having fun			
Reflection	0.80	3.05[c]	0.80
Having a chance to reflect			
Opportunities to work at my own pace			
Doing something physical			
Feeling peace of mind			
Individual items			
Feeling of doing something useful		4.39	
Making decisions about projects		2.10[b,c]	

Note: Same superscripts are not significantly different at $p < 0.05$.

Source: Ryan *et al*., 2001

Table 3.3. Save Our Streams volunteers' importance ratings for motivation factors for water quality monitoring.

Motivation Factors	Mean Importance[1]
To protect the environment	4.63
Learning	4.00
Teaching	3.67
To be of service	3.65
For nature enjoyment	3.00
Social	2.76
To guard against local threats	2.64
For career growth	1.83

[1] 1 = not at all important; 2 = slightly important; 3 = somewhat important; 4 = moderately important; 5 = very important.

Source: Roggenbuck *et al.*, 2001

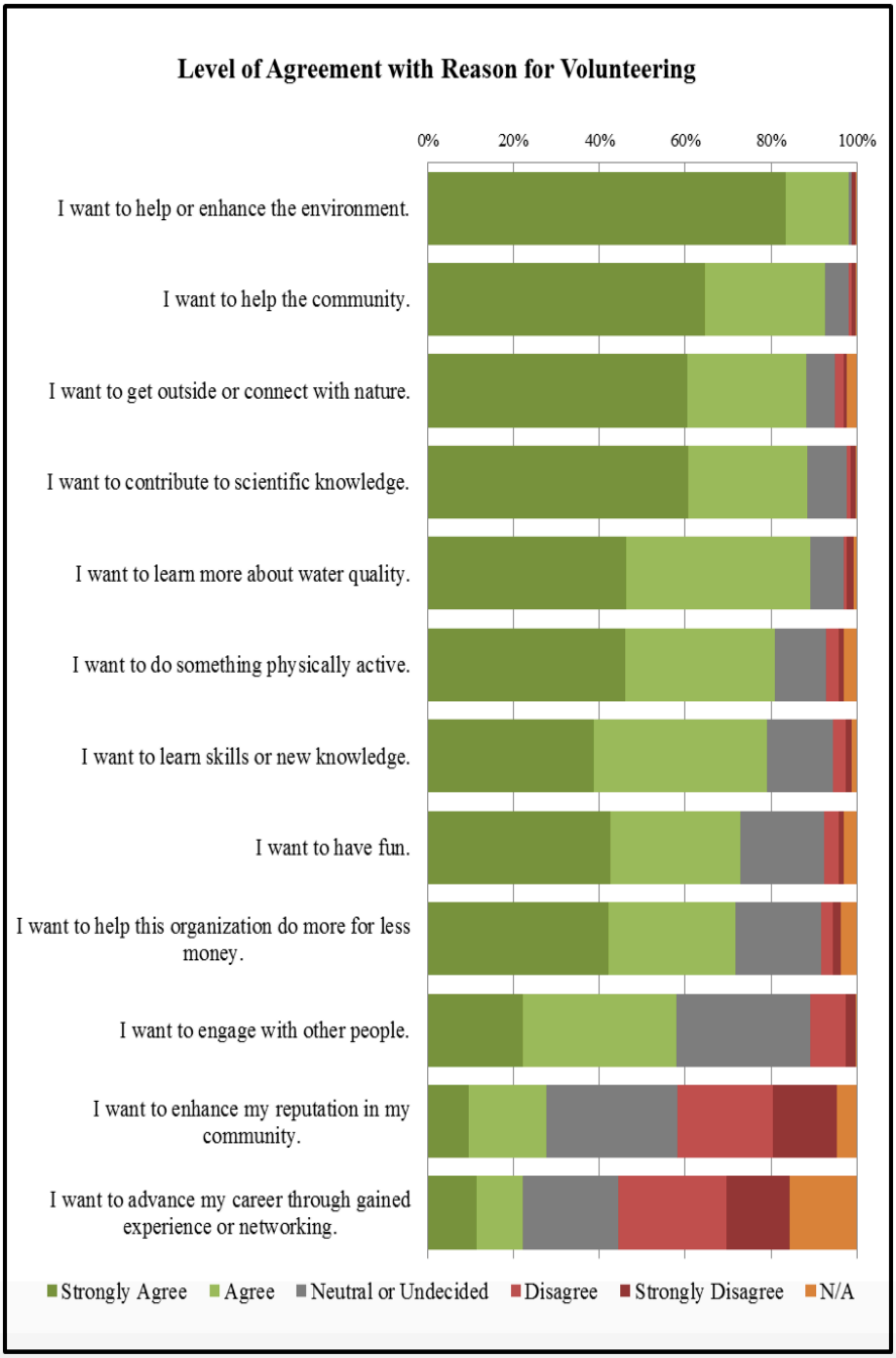

Figure 3.1. Frequency of responses for each motivation in order of strongest to weakest agreement. (Alender, 2016).

Another factor which strongly motivates volunteers is learning (Asah and Blahna, 2012; Jacobson *et al*., 2012; Ryan *et al*., 2001). People are motivated to volunteer because it permits new learning experiences and an opportunity to enhance knowledge and skills (Clary *et al*., 1998). Bell *et al*. (2008) found that creating an atmosphere of social learning (e.g. learning from more experienced volunteers and project leaders) was vital for sustaining participation.

Other motivations include making friends, having fun, getting outside, being active, working with friends, to be with like-minded people, etc. Alender (2016) found that many respondents agreed or strongly agreed with statements assessing motivations involving social interactions (Figure 3.2). Social factors often appear as a medium/low frequency motivator in studies (Asah and Blahna, 2012; Bruyere and Rappe, 2007; Jacobson *et al.,* 2012; Roggenbuck *et al*., 2001; Ryan *et al*., 2001).

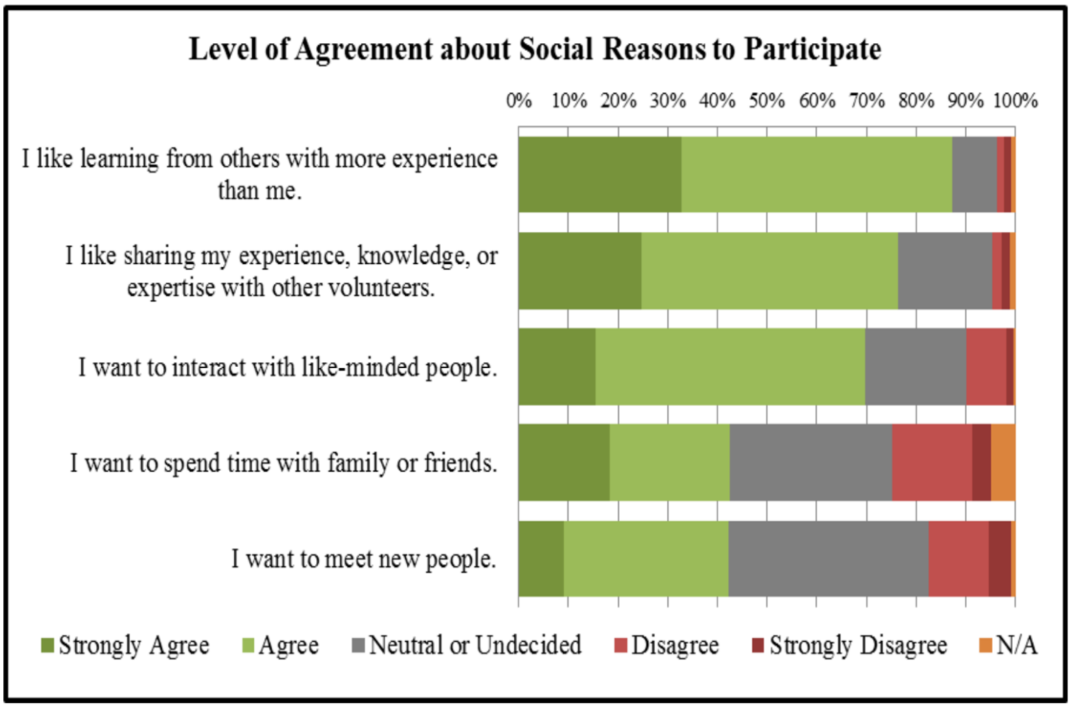

Figure 3.2. Frequency of responses for each statement about social interactions in order of strongest to weakest agreement. (Alender, 2016).

Location is also a factor affecting people's choice to volunteer, however, it is not frequently mentioned in the literature. Ryan *et al.* (2001) found that most lived within a 5-mile radius to volunteer sites. Alender (2015) suggests that a survey asking how far or how much time people are willing to travel would help recruiters to target people living within that radius.

People sometimes volunteer because they are concerned with the career-related benefits (Clary *et al.,* 1998), for example, they want to get their foot in the door for jobs. Many studies (Alender, 2016; Asah and Blahna, 2012; Bruyere and Rappe, 2007; Jacobson *et al*., 2012; King and Lynch, 1998; Roggenbuck *et al*., 2001) have found that this is a low frequency motivation to volunteer. This also relates to another motivation – having a pre-existing interest in the topic. Crowston and Prestopnik (2013) state that citizen science projects are often heavily dependent on citizens with a pre-existing enthusiasm for the topic.

The relationship between volunteers and project managers is of importance for retaining volunteers. If this relationship is not positive it can lead to volunteers dropping out and inactivity. Strong leadership and communication from project managers are particularly significant for maintaining a good relationship with volunteers. Volunteers from the Save Our Stream project expressed the need for more effective leadership and that strong, organised leadership is an important reason for sustained involvement (Roggenbuck *et al*., 2001). Bruyere and Rappe (2007), Jacobson *et al.* (2012) and Ryan *et al.* (2001) also reported that volunteers were motivated by good leadership and a well organised project. Martinez's (1998) study reported volunteers dropping out when they did not get enough follow up. Alender (2015) found that participants value communication of results and showed a strong desire for results to be shared with them. It is advised by Bell *et al.* (2008) that project managers should communicate the value and usefulness of volunteer data because this gives volunteers a feeling of having a purpose which is critical to retention. Regular communication of goals, expectations, outcomes and upcoming events has also been found to encourage volunteers to participate for longer (Rotman *et al.,* 2014).

Some literature has explored reasons why volunteers drop out. These include inadequate or overly complex technologies (causing frustration) (Rotman *et al.,* 2014), not having enough time, having too many other obligations, not having fun, failure to learn new skills, not enough training and not meeting people with similar interests (Martinez, 1998).

Understanding the numerous motivators to volunteer and also how they can change over time is key to a successful project. Knowledge of what motivates participants allows managers to tailor their projects and recruitment and retention strategies which helps reduce capital expense and time spent on ineffective techniques.

3.3 Methods

Survey 1

3.3.1 Survey Design

Survey 1 (Appendix 1) was designed to be short and consist mostly of closed questions for several reasons: (a) shorter surveys are easier for the respondent to fill out, (b) response rate may be higher, (c) a relatively high number of responses were desired, (d) given the time limits a closed question survey was most effective. These are common reasons why researchers design closed question surveys (Alender, 2015). One open question was included on motivations because a richer understanding with unanticipated responses was wanted.

The survey comprised of a short introduction and definition of the term citizen science, 13 questions and a thank you note. The first five questions collected demographic information on age, gender, level of education, employment status and occupation because this study wanted to explore how demographics may influence citizens' interest and motivations. The employment status question gives an indication of potential leisure time e.g. someone who is retired may have more time available than someone working full time.

The rest of the survey asked targeted questions about the level of interest in monitoring intermittent streams and what would motivate participation. An initial question of interest level was followed by several questions about certain factors including collecting data using a mobile phone, combining stream tracking with an existing hobby and knowing they were helping to increase scientific understanding of droughts, biodiversity and downstream water quality to investigate if these factors alter initial interest levels.

Multiple choice, binominal (yes, no) and Likert-type scale questions were used for this survey. Likert-type scale questions are often used as a method of measuring attitudes and opinions (Gliem and Gliem, 2003). A 5-point scale was chosen based on Dawes' (2008) study as well as for ease for the respondents. All questions required an answer in order to give a consistent sample size for each question.

3.3.2 Data Collection

To recruit respondents for survey 1, environmental organisations across Colorado were contacted via email explaining the study and its importance and asked if they would be willing to share the survey in their newsletter or on their social media. The City of Fort Collins Natural Areas Department, The Coalition for the Poudre Watershed, Colorado Wildlands Restoration Volunteers, Colorado's Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) and Estes Park Environmental Centre all shared the survey. The reason these organisations were targeted was because they have contact with citizens who may have an interest in monitoring intermittent streams. Sharing the survey with a broader audience would have given a richer sample size, however, this method would have taken more time than was available. Therefore, although this sampling technique is greatly limited, results can still be used by projects to improve recruitment and retention by informing project managers on what increases interest and what motivates participation.

3.3.3 Data Analysis

Qualitative data were analysed using content analysis. Responses were analysed one by one to identify key themes. Each response was coded depending on theme. Some responses were split in two because each part fitted into different themes, for example, a respondent may have part of their response in one theme and part in another theme. Themes were then narrowed down to 10 key themes. Quantitative data were analysed using descriptive statistics including percentages, pie charts and clustered bar charts.

3.4 Results and Discussion

3.4.1 Demographics

Survey 1 generated 131 responses in total. The demographics of respondents are shown in Figures 3.3 - 3.6.

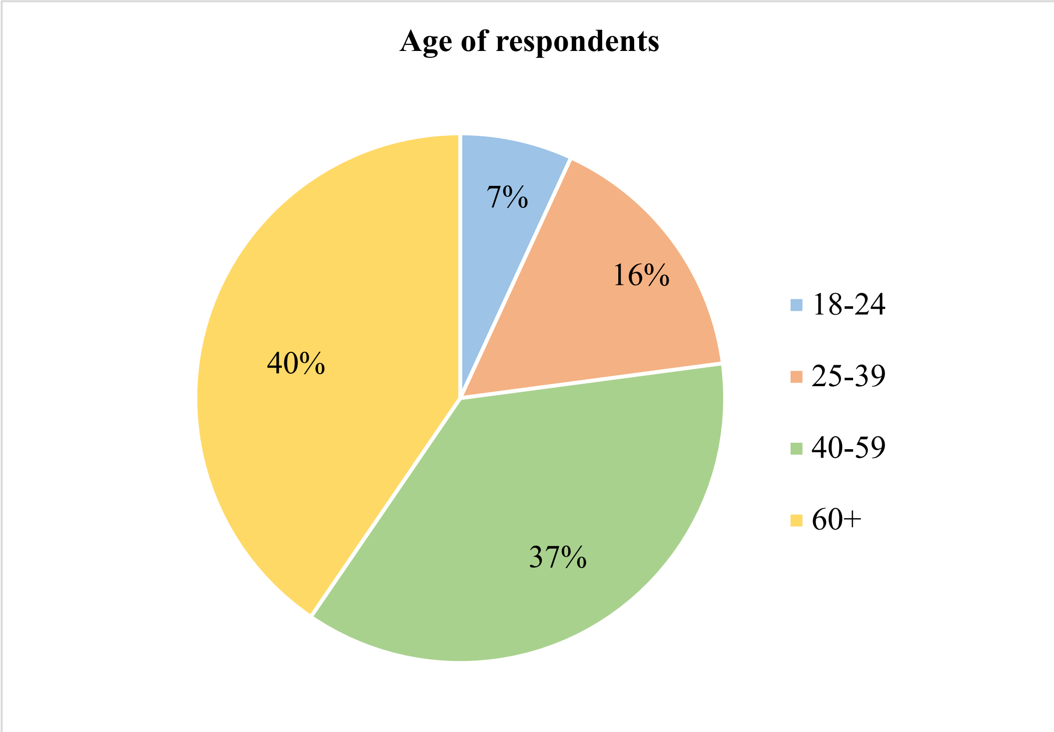

Figure 3.3. Age distribution of respondents to survey 1.

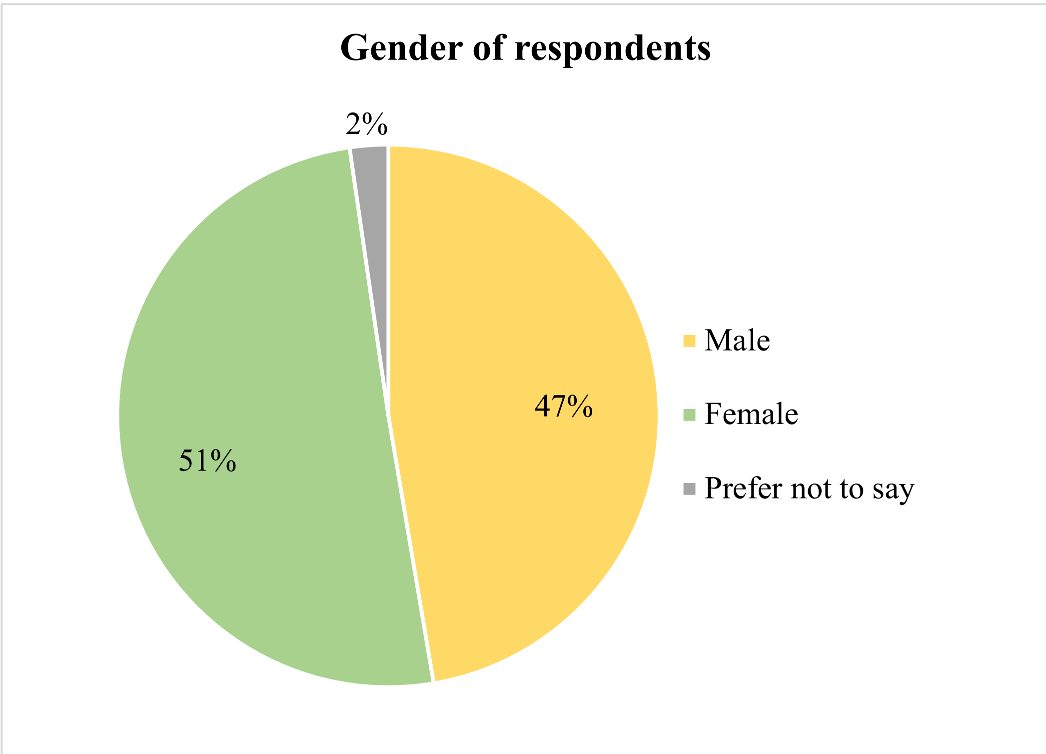

Figure 3.4. Gender distribution of respondents to survey 1.

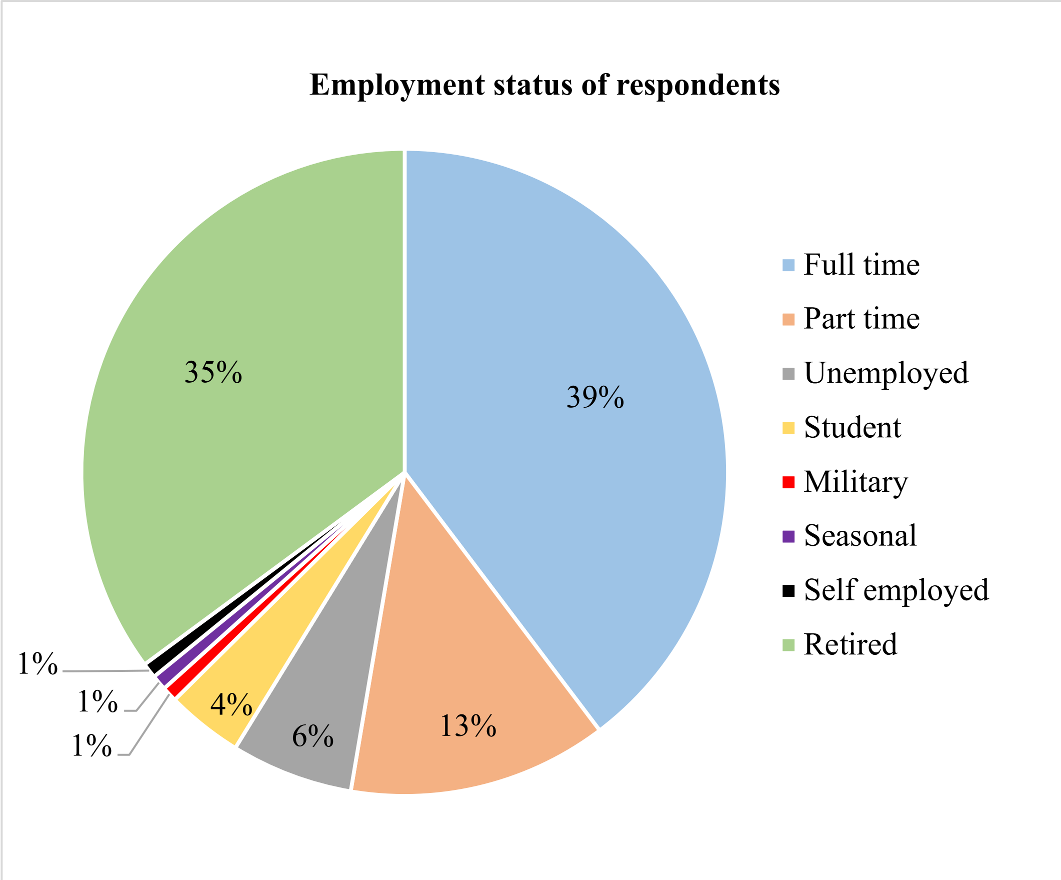

Figure 3.5. Employment status of respondents to survey 1.

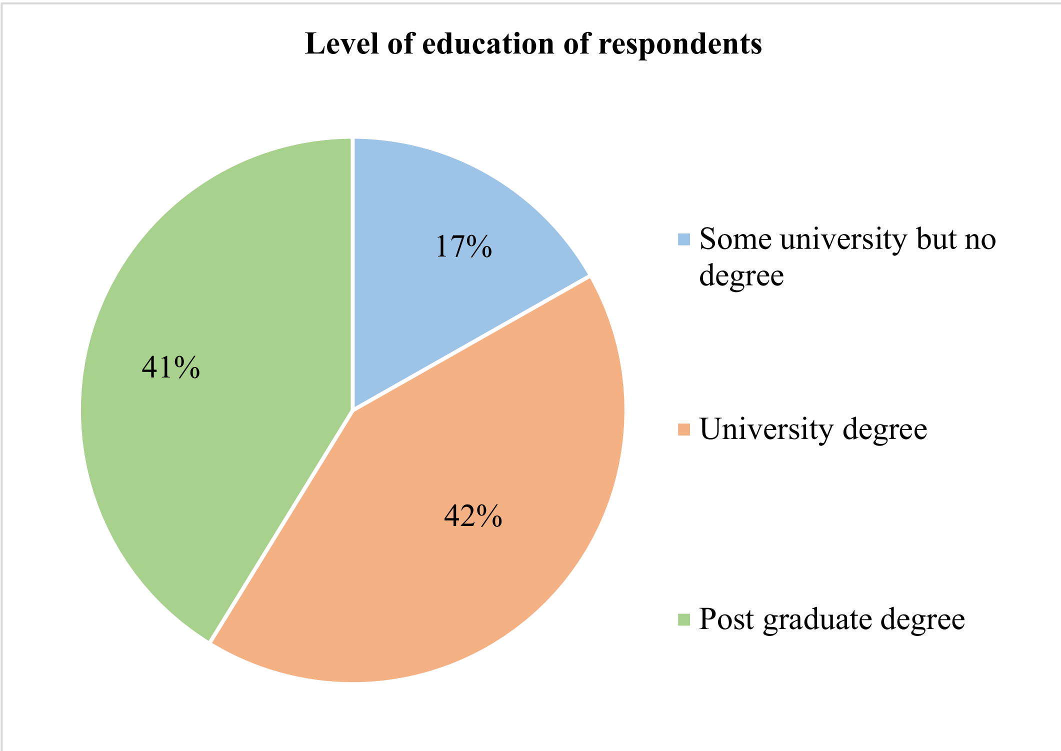

Figure 3.6. Education level of respondents to survey 1.

3.4.2 Citizens' level of interest

Firstly, participants were asked what their initial interest was in monitoring the streamflow of intermittent streams. Results show that 90% of respondents were either somewhat interested, interested or extremely interested (Figure 3.7a). Demographically, no major variations were found.

These results are limited because some demographic categories had very low sample sizes e.g. only one respondent was from the military. Because these sample sizes are not representative conclusions cannot reliably be drawn from them. However, all respondents heard about the survey through a nature-focused organisation and expressed a high level of interest. Therefore, one suggestion can be drawn from these results; project managers could advertise a project through the organisations who shared the survey (listed in section 3.3.2). This technique may help recruit interested participants for stream monitoring.

To take a deeper look into what affects how interested citizens are in monitoring streams three scenarios were given in survey 1 and respondents answered how interested they were in each. Figure 3.7a shows level of interest in each scenario and Figure 3.7b shows the change in interest (increase, decrease or no change) from initial interest.

The first scenario measured level of interest if you could use an application (app) on your mobile phone to monitor streams (second bar of Figure 3.7a). For this scenario 62% of respondents indicated no change in interest from their initial interest, 18% of respondents increased their interest and 21% decreased their interest (Figure 3.7b). Unsurprisingly, the 60+ age group showed the greatest decrease in interest and the majority of the 21% who decreased their interest were retired people (Appendix 2). No major differences were detected between genders, level of education or employment status (Appendix 2). From these results, project managers would be advised that when selling the project to retired citizens and citizens aged 60 or older, advertising the ability to monitor using mobile phones should not be a main focus. These results also show that projects still need to provide paper data sheets to include people who do not want to or can't participate using their mobile phone.

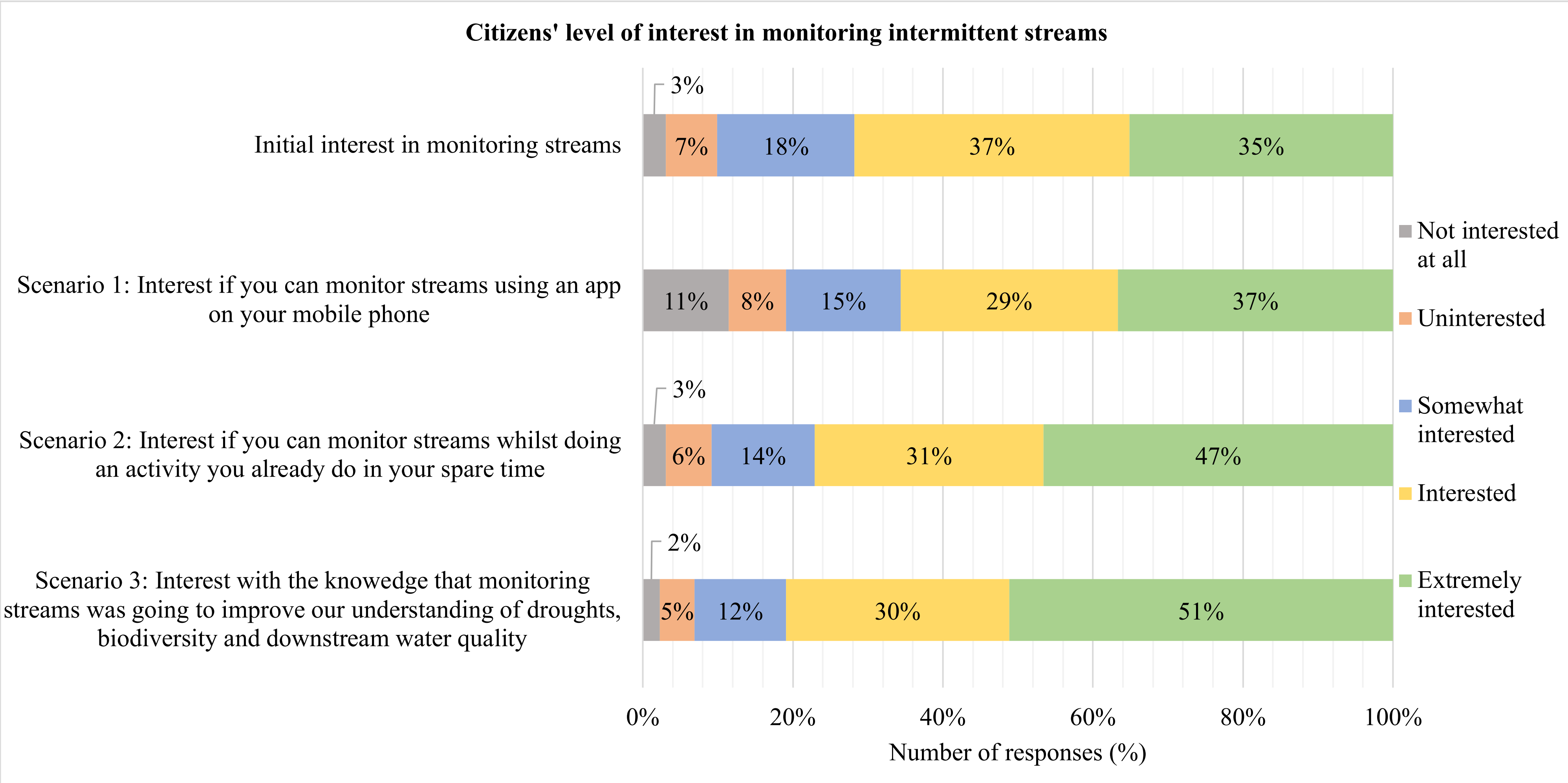

Figure 3.7a. Citizen' level of interest in monitoring intermittent streams in three scenarios.

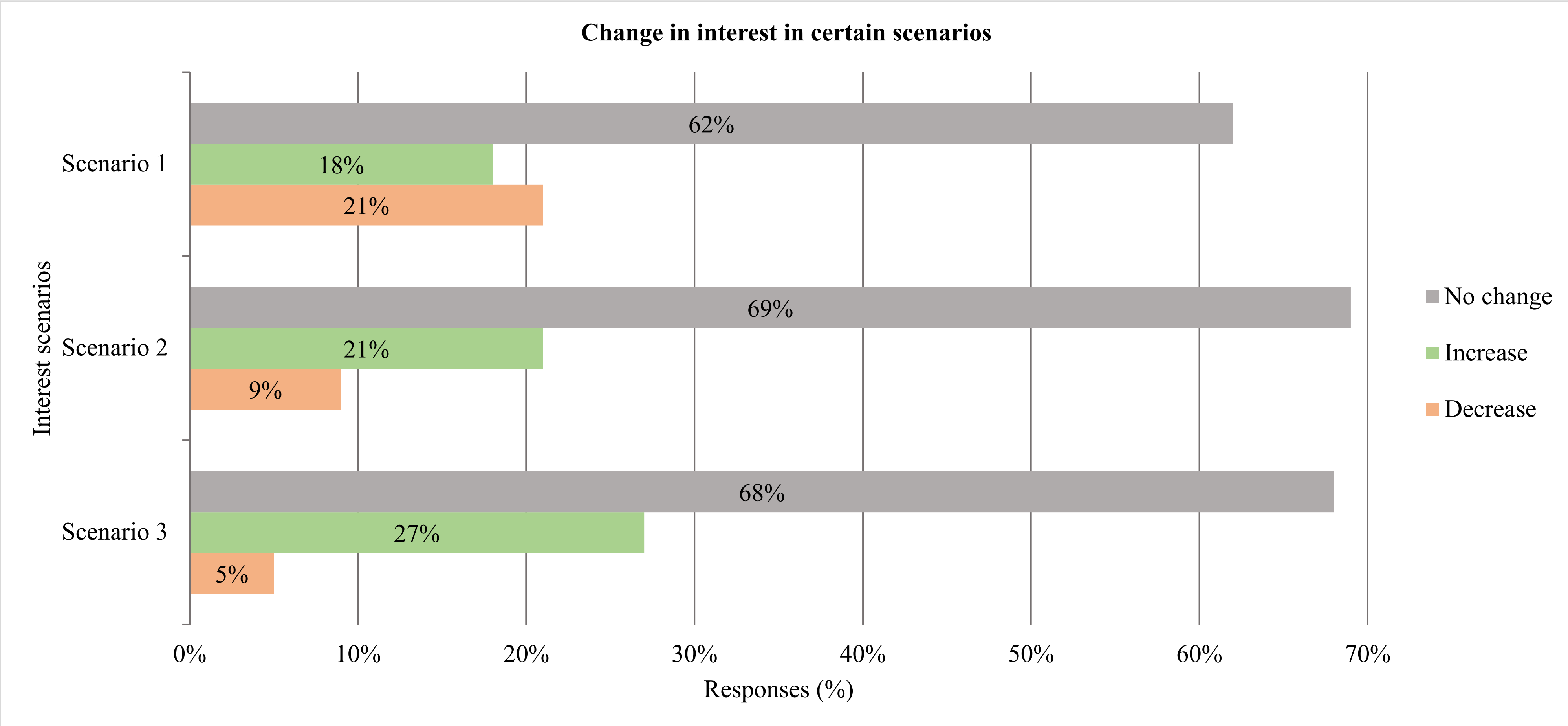

Figure 3.7b. Change in interest from initial interest for three scenarios. Scenarios given in Figure 3.7a.

The second scenario measured level of interest if you could monitor streams whilst doing an already existent hobby. Respondents were asked which of the following hobbies they enjoyed: running, hiking, biking, horse riding and going on a road trip. They were then told that they could do these hobbies and monitor streams at the same time. Figure 3.7b shows how interest changed given this information. Interest increased in 21% of respondents and decreased for 9% of respondents. Results showed that there are no major demographic differences for this scenario, apart from respondents who work full time showed a greater increase in interest than any other employment status (Appendix 3). This may be because people who work full time might not have the time to participate in a citizen science project but knowing they can do it whilst doing something they already do makes them more interested. This scenario revealed that advertising stream monitoring as something you can do alongside an existing hobby is likely to be a successful technique.

The third scenario asked respondents how interested they are with the knowledge that participating would help improve our understanding of droughts, biodiversity and downstream water quality. This scenario generated the most interest. Figure 3.7a shows that only 7% showed no interest and 51% were extremely interested. Furthermore, this scenario had the greatest increase in interest (27%) and lowest decrease in interest (5%) (Figure 3.7b). This scenario appealed more to respondents who had a degree (Appendix 4). Respondents who did not have a degree had a lower increase in interest compared to respondents with a university or post-graduate degree. This may indicate that respondents without a degree are less interested in participating in order to improve scientific understanding of intermittent streams. This could be because they are unaware of the importance of intermittent streams. Advertising a project for monitoring streams as helping to improve our understanding will most likely be an effective technique to recruit participants because several respondents indicated an increase in interest. However, the results clearly show that helping improve understanding of intermittent streams is not important to some people. Therefore, this factor should not be advertised alone but alongside other factors.

3.4.3 Citizens' motivations

Respondents were asked what would motivate them to participate in a citizen science project to monitor intermittent streams. Results were organised into 10 categories. Table 3.4 gives example quotes for each category and the frequency of responses.

Table 3.4. Frequency of responses to participate in a citizen science project to monitor intermittent streams. Green = high motivator, yellow = medium motivator, orange = low motivator.

Motivation Category	Example quotes	Responses frequency
Location	*"Close proximity of streams to my house."*	23
	"If streams were in a neat place to visit."	
Contribute	*"Actively contributing to data collection in a meaningful way."*	21
	"To know that it would help scientists."	
Pre-existing interest	*"Because of the effects of climate change, stream monitoring is increasingly important to assessing Colorado ecosystem health, public availability and local economies."*	16
	"I'm passionate about stream ecology and keeping our waterways healthy."	
Recreational	*"Getting outside."*	14
	"Fishing opportunities."	
Access to data and feedback	*"Having the ability to access data from the past and present, and in real time. Would also like to have access to future results, especially is they were to make it all the way to publication."*	14
	"Evidence that the data would be important, that there is some situation that might be improved or would be clarified by the data."	
Learning	*"To learn about small streams from others during the project."*	11

	"Teach a class at a local high school, we are always looking for these types of projects for service learning."	
Time	*"Low time commitment."*	11
	"Time flexibility."	
Environmental values	*"I would like to help us improve the quality of the environment."*	8
	"Environmental stewardship."	
Career	*"Alignment with career and interests."*	4
	"I work professionally with water and find it interesting."	
Social	*"To be part of our community."*	3
	"Ability to involve my kids."	

The most frequent motivation recorded was location (Table 3.4). Respondents said they would monitor a stream if it was within walking distance of their house, work or recreation area. Monitoring sites in a nice location was also a motivator. Finding that location is the most important motivator was unexpected. No other studies reviewed indicated location as a highly important factor with the exception of Ryan *et al.* (2001) who found that most participants lived within a 5-mile radius. As Alender (2015) suggested, a survey asking how far or how much time people are willing to travel would be useful. Such a survey is highly advised given the importance citizens have expressed about location.

The second most frequent motivation was to contribute. This finding links to the third scenario in section 3.4.2. Citizens indicated that they enjoy supporting the scientific community. This was another unexpected finding because this factor did not commonly appear as an important motivator in the literature. However, Alender (2016) did find that to contribute to scientific knowledge was the fourth most frequent reason for volunteering (Figure 3.1).

Many citizens also had a pre-existing interest in water (Table 3.4). Respondents indicated that they were interested in watershed health and wanted to know more about their nearby streams. Being the third most important motivator, this finding proves Crowston and Prestopnik (2013) right that most citizen science projects are heavily reliant on citizens with a pre-existing enthusiasm for the topic.

Motivators of medium importance included recreation, access to data and feedback and time. Results in Table 3.4 show that enjoying nature, such as getting outside or fishing, was a motivator of medium importance. Both Alender's (2016) and Roggenbuck *et al.*'s (2001) studies reflect this finding (Table 3.3 and Figure 3.1). Respondents also wanted to be able to access data and see evidence of how their work has been helpful and useful (this links to a finding in section 5.4.1). Additionally, respondents were willing to participate if their time could be flexible, if they could fit it into their schedule and if they didn't have to commit a lot of their time.

The motivation to learn was also a motivator of medium importance. The two quotes in Table 3.4 reflect what Alender (2016) found: that participants like learning from others with more experience and those with more knowledge like to share that with other volunteers. Bell *et al*. (2008) found that this sort of social learning was vital to retaining participants.

Surprisingly, environmental values were a motivator of low importance. This was unexpected because for a larger number of the reviewed studies, wanting to help the environment was the top motivator. This may reveal a flaw with using a set list of motivators in surveys and asking respondents to indicate how strongly they agree with each. Respondents may say they are strongly motivated by wanting to help the environment in order to look good when actually this may not be a main motivator.

Similar to much of the reviewed literature, career was a motivator of low importance. However, like Brugere and Rappe's (2007) study, the majority of respondents were not of the age where they are looking for a career. Nevertheless, it's appearance indicates that career-related benefits are still of importance to some citizens.

Finally, social motivations (for example, to be part of the community) generated the least responses. This finding is reflected in the literature too (Roggenbuck *et al.,* 2001; Ryan *et al.,* 2001).

3.5 Conclusion

This chapter has responded to research question 1. An online survey investigating how interested citizens are in monitoring intermittent streams and what their motivations are yielded 131 responses. Results indicated a very high level of interest; 90% were somewhat interested, interested or extremely interested. Interest increased with the knowledge that stream monitoring can be done whilst doing a pre-existing hobby and will help improve our understanding of drought, biodiversity and downstream water quality. Location of streams, to contribute to research and having a pre-existing interest in water were the top three motivations. Environmental values, career and social motivations were the three least frequent motivations. These results help project managers understand what interests and motivates citizens to monitor streams and can be used to help design new recruitment and retention techniques to increase participation. Socially successful citizen science projects can be designed with the help of these results.

Chapter 4: Scientists' Perceptions

4.1 Introduction

This chapter responds to research question 2; how do scientists perceive citizen science as a way to monitor intermittent streams? The chapter reviews the literature (section 4.2), describes the methods used (section 4.3), presents and discusses results (section 4.4) and ends with a conclusion (section 4.5).

4.2 Literature Review

The quality of data collected by citizen scientists is a challenge which all citizen science projects face and must address. Despite the general enthusiasm about citizen science, there are many scientists that are more conservative and unenthusiastic about the contribution citizen science can make to science (Riesch and Potter, 2014). It is a common perception that citizen science data lacks quality and is therefore unsuitable and unworthy of being used in serious scientific research (Hunter *et al.,* 2013) or by decision makers (Conrad and Hilchey, 2011; Gouveia *et al.,* 2004). There is a plethora of reasons why some scientists are sceptical about citizen science data.

The limited training of citizen scientists is one of the greatest concerns (Hunter *et al.,* 2013). It has been reported that several researchers are not confident that citizen scientists' level of training is sufficient to prevent false positive and false negative data (Conrad and Hilchey, 2011). Scientists are also concerned that training is inconsistent and suboptimal (Conrad and Hilchey, 2011). It is believed that substantial training and experience is needed in order to collect accurate data (Thompson and Mapstone, 1997). Burgess *et al.* (2017) found that some scientists thought that adequately trained citizens could collect their data. The authors also found that in-person training by experts is preferred. Citizen scientists' lack of training can be overcome but it still remains a prominent concern amongst the scientific community.

Poorly designed projects and methods of data collection are further important concerns. Paulos (2009) said that because citizen science projects are designed to invite non-scientists to collect data, the scientific method is not commonly included in the framework. If that is the case, consequentially data will most likely be noisy and inaccurate (Paulos, 2009). The mistrust in the credibility of citizen science data is deepened when studies lack experimental design and don't account for issues such a sampling size (Conrad and Hilchey, 2011). Newman *et al*. (2003) and Krasny and Bonney (2005) also mention the critique that citizen science does not give attention to study design. It is evident therefore that scientifically rigorous data rests on well designed and standardised data collection methods (Cohn, 2008; Silvertown, 2009).

Training and design are the two most prominent concerns, however, there are several more worries expressed in the literature. One example is observer biases (Delaney *et al.,* 2008; Dickinson *et al.,* 2010; Galloway *et al*., 2006). The relative anonymity can lead to malicious data being submitted (Foster-Smith and Evans, 2003) and data can be discredited as being politically motivated (Jalbert and Kinchy, 2016). A further concern is the lack of commitment of volunteers (Foster-Smith and Evans, 2003; Galloway *et al.,* 2006). This can lead to both spatial and temporal data gaps and inconsistencies (Hunter *et al.,* 2013). Another worry noted by Cohn (2008), Dickinson *et al.* (2010) and Bonter and Cooper (2012) is problems with or the absence of standardisation and verification methods.

As a result of the numerous concerns and worries, the scientific community are often reluctant to accept citizen science (Delaney *et al.,* 2008) and perceive data as unworthy of use in scientific research (Hunter *et al*., 2013). Riesch and Potter (2014) found that many scientists were concerned about how the wider scientific community would receive their work rather than the actual quality of the data itself. Publication rates of citizen science data evidences that citizen science is still not frequently used as a primary research tool (Burgess *et al*., 2017). In the fields of ecology and conservation, peer reviewed studies have only been published at a modest rate and have rarely produced highly cited data (Jiguet *et al.,* 2005; Silvertown *et al*., 2011). Burgess *et al* (2017) also found that scientists value data from other scientists and academics more than that collected by citizen scientists because they believe the data suffers from low quality. Evidently, citizen science is suffering from an image problem – it has to persuade reviewers, the wider scientific community and potential participating scientists that it is worth working on (Riesch and Potter, 2014).

However, Riesch and Potter (2014) interestingly also found that perceived lack of positivity about citizen science from the scientific community was more often anticipated rather than actual. Despite expectations, the reception of results of citizen science projects that have been peer reviewed has been more positive than negative (Riesch and Potter, 2014). Numerous studies have also found that citizen scientists can collect data that is of comparable quality to data collected by professionals (Jollymore *et al.,* 2017). Examples include Danielsen *et al*., (2014), Delaney *et al*., (2008), Elbroch *et al*., (2011), Forrester *et al.,* (2015), Lewandowski and Specht, (2015), Lin *et al*., (2015), Sullivan *et al*., (2014). Devictor *et al*. (2010) and Edgar *et al.* (2014) also serve as examples of studies having produced well-known and highly cited data. Furthermore, many citizen scientists have experience or education in a topic or may have the necessary knowledge (e.g. an avid bird watcher) which suggests that they could be just as capable as professional scientists of collecting data (Crownston and Prestopnik, 2013; Lewandowski and Specht, 2015).

It is clear from a review of the literature that although there is a lot of enthusiasm about citizen science and many studies have shown that citizen scientists can collect high quality data, there is still a great deal of scepticism. This scepticism is preventing many scientists from using citizen science data and seeing it as data which can inform scientific inquiry and decision making. The issues surrounding scientists' perceptions requires further reflection in the literature (Riesch and Potter, 2014) and further investigation in scientific studies as it is evidently concerning scientists.

4.3 Methods

Survey 2

4.3.1 Survey Design

Survey 2 (Appendix 5) was designed to be short for the same reasons given in section 3.3.1. This survey included comment boxes which gave respondents the opportunity to explain their answers to the closed questions. This resulted in quantitative as well as qualitative data in order to give a richer understanding of scientists' perceptions. Only the closed questions required an answer; the open questions were optional so do not have a consistent sample size.

The survey comprised of a short introduction and definition of the term citizen science, 19 questions and a thank you note. The first three questions collected demographic information on age, gender and level of education because this study wanted to investigate whether scientists' perceptions varied demographically.

The rest of the survey asked a series of questions about how engaged they are with citizen science, whether they would like to engage citizen scientists in their area of research, what their perceptions are of the quality of citizen science data, how they think the wider scientific community perceives citizen science and whether they think citizen science is a good method in a series of scenarios.

The same types of questions described in section 3.3.1 were also used in survey 2.

4.3.2 Data Collection

To recruit respondents, scientists working in environmental research fields were identified using Colorado State University's directory of staff from The Collage of Natural Resources. This yielded 912 possible survey respondents. Each staff member in the directory was emailed explaining the research and asking them to complete the survey.

4.3.3 Data Analysis

Data were analysed using the same methods as section 3.3.1.

4.4 Results and Discussion

4.4.1 Demographics

Survey 2 generated 42 responses. The response rate was 4.6% which is low but not atypical for such a survey. The demographics of respondents are shown in Figures 4.1-4.3.

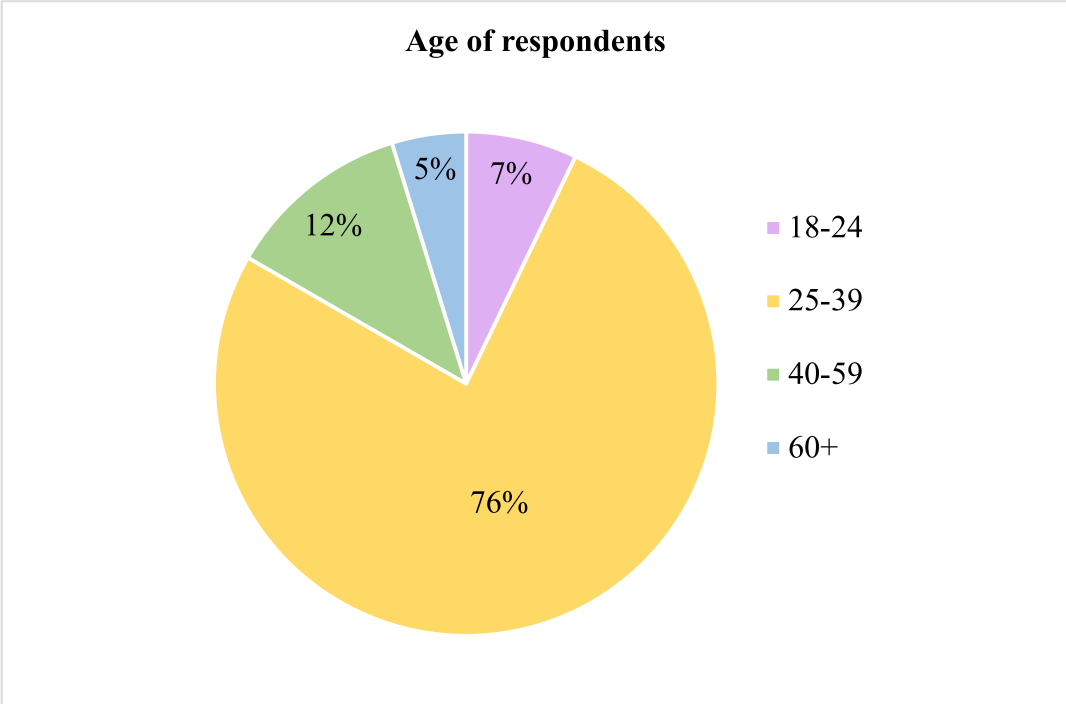

Figure 4.1. Age distribution of respondents to survey 2.

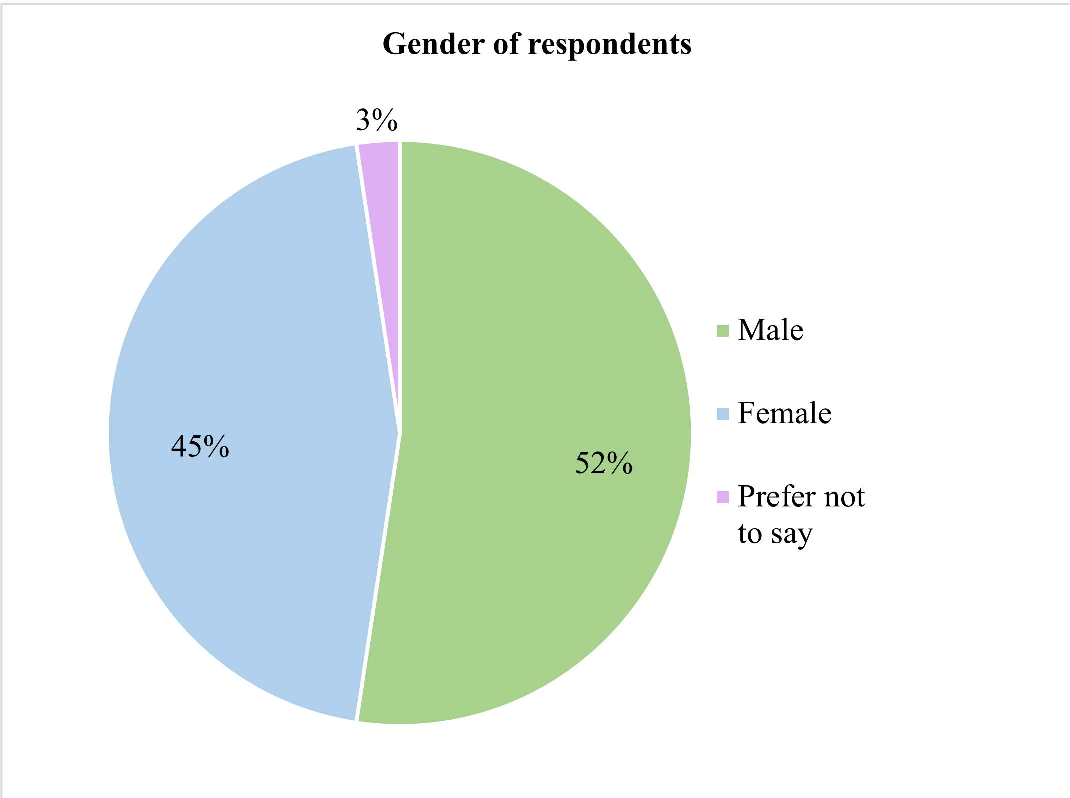

Figure 4.2. Gender distribution of respondents to survey 2.

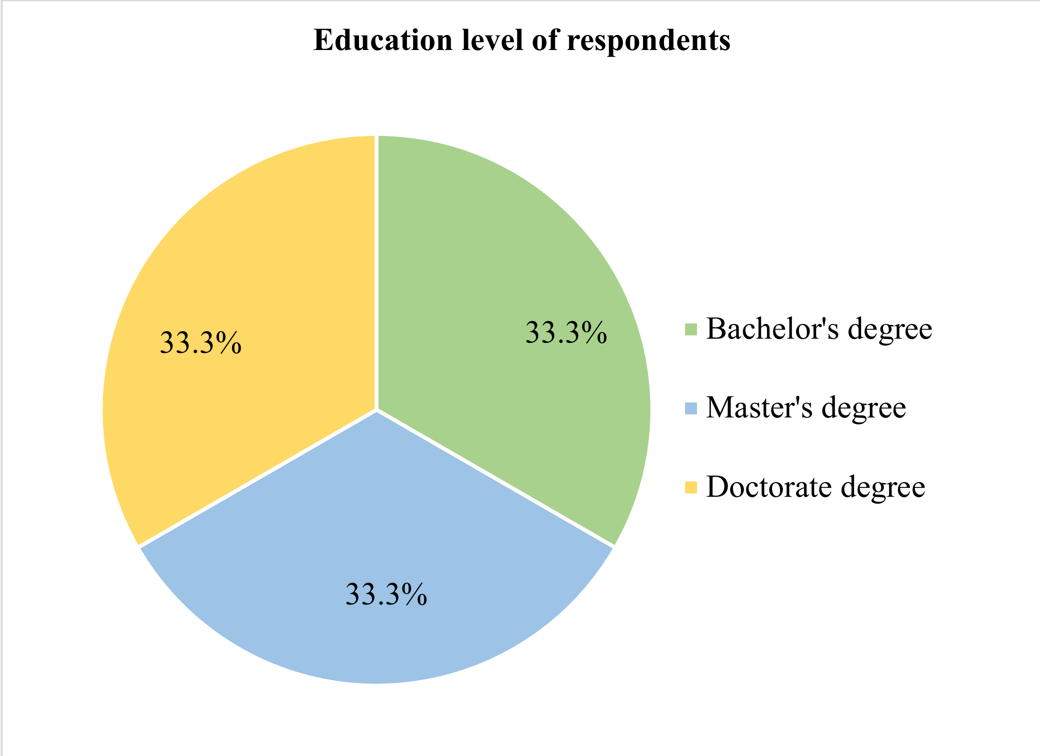

Figure 4.3. Education level of respondents to survey 2.

4.4.2 Perceptions

Scientists were firstly asked a number of questions to build a picture of how they perceive citizen science. 69% of respondents believed that data collected by citizen scientists is of comparable quality to data collected by professional scientists (Figure 4.4). 95% believed that data collected by citizen scientists can be used to publish papers (Figure 4.5). These initial findings indicate that scientists at CSU are mainly positive about citizen science.

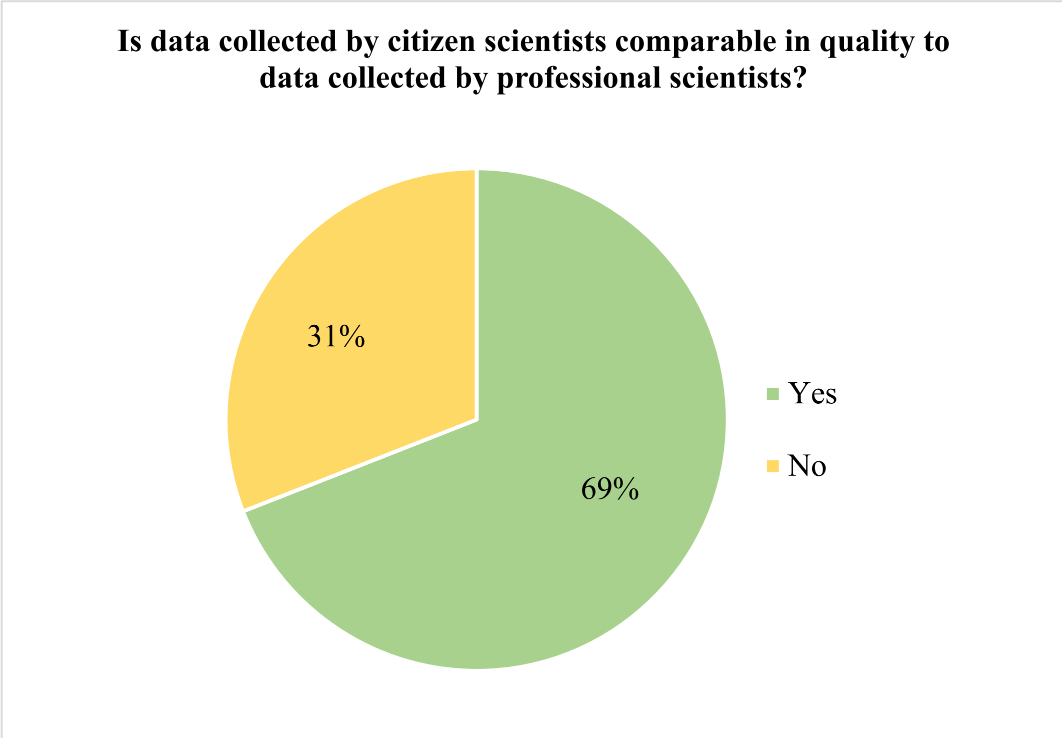

Figure 4.4. Responses from survey 2 about whether citizen scientists can collect data that is of comparable quality to data collected by professional scientists.

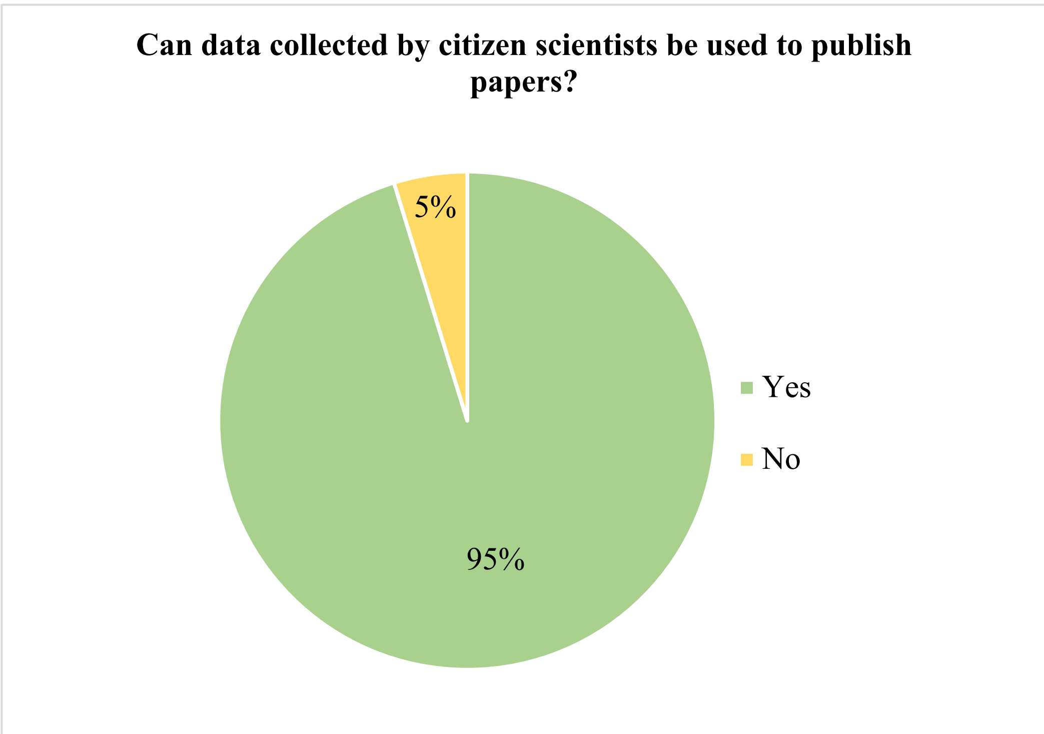

Figure 4.5. Responses from survey 2 about whether citizen science data can be used to publish papers.

To focus on the type of citizen science that monitoring intermittent streams involves, scientists were asked how much they agreed with three statements (Figure 4.6). 83% of respondents said they either agreed or strongly agreed that citizen science is good when collecting data on the presence or absence of something. This is positive as it indicates that scientists are likely to be accepting of data collected by citizen scientists on the presence or absence of flow in streams. A large proportion (78%) also agreed or strongly agreed that citizen science is good when collecting data at a large geographic scale. This suggests that there is hope that large scale data collected by citizen scientists will be accepted. The third statement did not have as much support. Only 29% agreed that citizen science is good when data is very time consuming to collect.

When asked how they thought the wider scientific community perceive citizen science, respondents were mainly positive. Table 4.1 shows that 38% of respondents thought that the scientific community perceive citizen science positively. Respondents indicated that they thought citizen science was gaining more respect and beginning to be seen as a viable data source. 26% of respondents thought perceptions were both positive and negative. They thought that although the scientific community may recognise the benefits of citizen science there is still a reluctance amongst scientists and many continue to dismiss it as unreliable and a waste of time. 19% responded neutrally and 17% thought perceptions were negative. Responses indicated that some scientists think the scientific community don't think citizen science is reliable, is not a good primary data source and is even 'not real science'. These findings reflect the mixed feelings documented in the literature. However, as Riesch and Potter (2014) found, the perception that the scientific community will not receive citizen science data positively could be anticipated rather than actual. It is beyond the ability of this dissertation to investigate this, but future research should explore this issue.

General conclusions cannot be draw from these results. However, the results do imply that citizen science data on intermittent streams are likely to have a positive reception from the scientific community based at CSU.

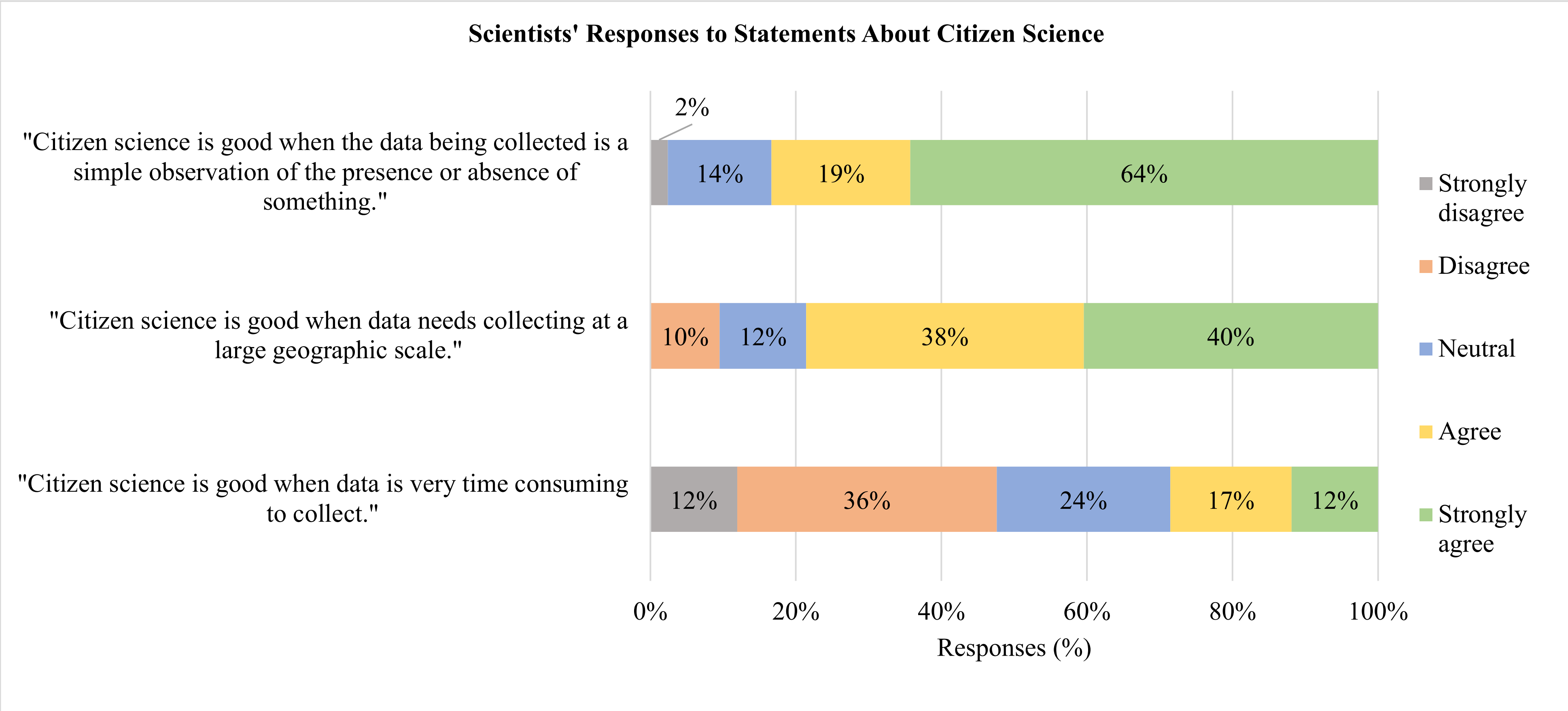

Figure 4.6. Scientists' level of agreement with three statements about citizen science.

Table 4.1. Responses of scientists when asked how they think the wider scientific community perceives citizen science.

Response Category	Example quotes	Responses frequency
Positively	*21. "Generally I believe citizen science is quickly gaining momentum and respect. The more it's used in peer-reviewed publications, the more people are considering it as a viable data source."*	16
	25. "I believe it is gaining recognition and popularity, especially at local scales. Scientists are beginning to appreciate and value engaging the public."	
Both positively and negatively	*34. "I think it's a spectrum. Some think it's great and can dramatically scale up research, while others think it's a waste of time and a passing trend."*	11
	40. "Wide variation, with the distribution being mildly interested but mostly dismissive. The interest comes with engaging citizens in nature studies in a hands-on manner -- this is always seen as a good thing. The dismissive part comes when structuring their own research and not even thinking about citizen science as an option."	
Neutral	*13. "Never discussed it."*	8
	4. "Probably not too much."	
Negatively	*5. "That it's not reliable and not real science."*	7
	42. "That it's not usually a good primary source for publications/data analysis."	

4.4.3 Training and Design

Two key themes were highlighted through content analysis of the qualitative data from survey 2: training and project design. These were also the two key themes found in the literature review. Training and project design were highlighted by respondents as two highly important areas for citizen science and its success.

The word 'training' (or trained or train) appeared 50 times in the qualitative data produced by survey 2. Conrad and Hilchey (2011) reported that several researchers are not confident with the level of training of citizen scientists. Some respondents reflected that concern.

> *"…the general public will likely not be as stringent as scientists on data integrity.…or they may not see some observation as important to document whereas a scientist would."*
>
> *"A hobbyist off the street will never have the same skillset as a trained professional scientist."*

A few respondents believed citizen scientists needed substantial training in order to collect accurate data (this reflects Thompson and Mapstone's (1997) finding).

> *"…it would require high levels of training and oversight."*
>
> *"The public would need a lot of training to provide useful data."*

Other respondents were more confident that citizens can be trained and showed a willingness to allow for citizens to be trained rather than writing them off.

> *"…any skillset can be cultivated if given the right opportunity."*
>
> *"…it doesn't take long to make sure people know what they are doing in terms of short training programmes."*

There are some varying opinions on training, but all agree that it is essential if data is going to be used and accepted.

Project design, including methods, protocols and goals is also of great importance. The responses from scientists reiterate the literature: high quality data is dependent on well-designed projects.

> *"…a better design will produce more reliable data."*

> *"If protocols are consistent and simple, then data quality from citizens should be equivalent to that from scientists."*

> *"If the research is well-designed…errors should be somewhat controlled for."*

4.5 Conclusion

This chapter has responded to research question 2. An online survey of 42 scientists from CSU revealed a generally positive perception of citizen science. A large proportion of respondents agreed that data collected by citizen scientists can be of comparable quality to data collected by professional scientists and can be used to publish papers. The majority of scientists also believed citizen science was good when data collection is an observation of the presence or absence of something and when data needs collecting at a large geographic scale. Respondents mainly thought that the wider scientific community perceive citizen science positively. Results also revealed that training and design are the two most important aspects of citizen science projects and are essential for high quality data. These results can be used to help design scientifically successful citizen science projects.

Chapter 5: Stream Tracker Case Study

5.1 Introduction

The purpose of this case study is to investigate what lessons can be learned from an existing citizen science project that is monitoring intermittent streams. The case study contributes to research question 1; what interests and motivates citizens to monitor intermittent streams?, and 3; how useful is citizen science for producing high quality flow data on intermittent streams? First a background of the case study, Stream Tracker, is provided (section 5.2). Secondly, the three methods used are described (section 5.3). Thirdly, results are presented and discussed (section 5.4). Finally, this chapter ends with a conclusion (section 5.5).

5.2 Background

In June 2017 Stream Tracker (Figure 5.1) was launched by a team from The Warner College of Natural Resources at CSU. Stream Tracker is a community powered stream monitoring project to improve the mapping and monitoring of intermittent streams through crowdsourced on the ground observations of streamflow presence and absence (Figure 5.2). Participating in Stream Tracker involves navigating to a point using the maps.me mobile application (Figure 5.3) or a global positioning system (GPS) (which citizen science projects are increasingly taking advantage of (Crall *et al.,* 2010)). At the site the presence or absence of flow is recorded using the CitSci.org application (Figure 5.4) or a paper data sheet (Figure 5.5). The CitSci.org application automatically enters your location coordinates, time and data and gives you the option to upload photos as well.

STREAMTRACKER

Community Powered Stream Monitoring

Figure 5.1. Stream Tracker Project logo. (Stream Tracker, 2017)

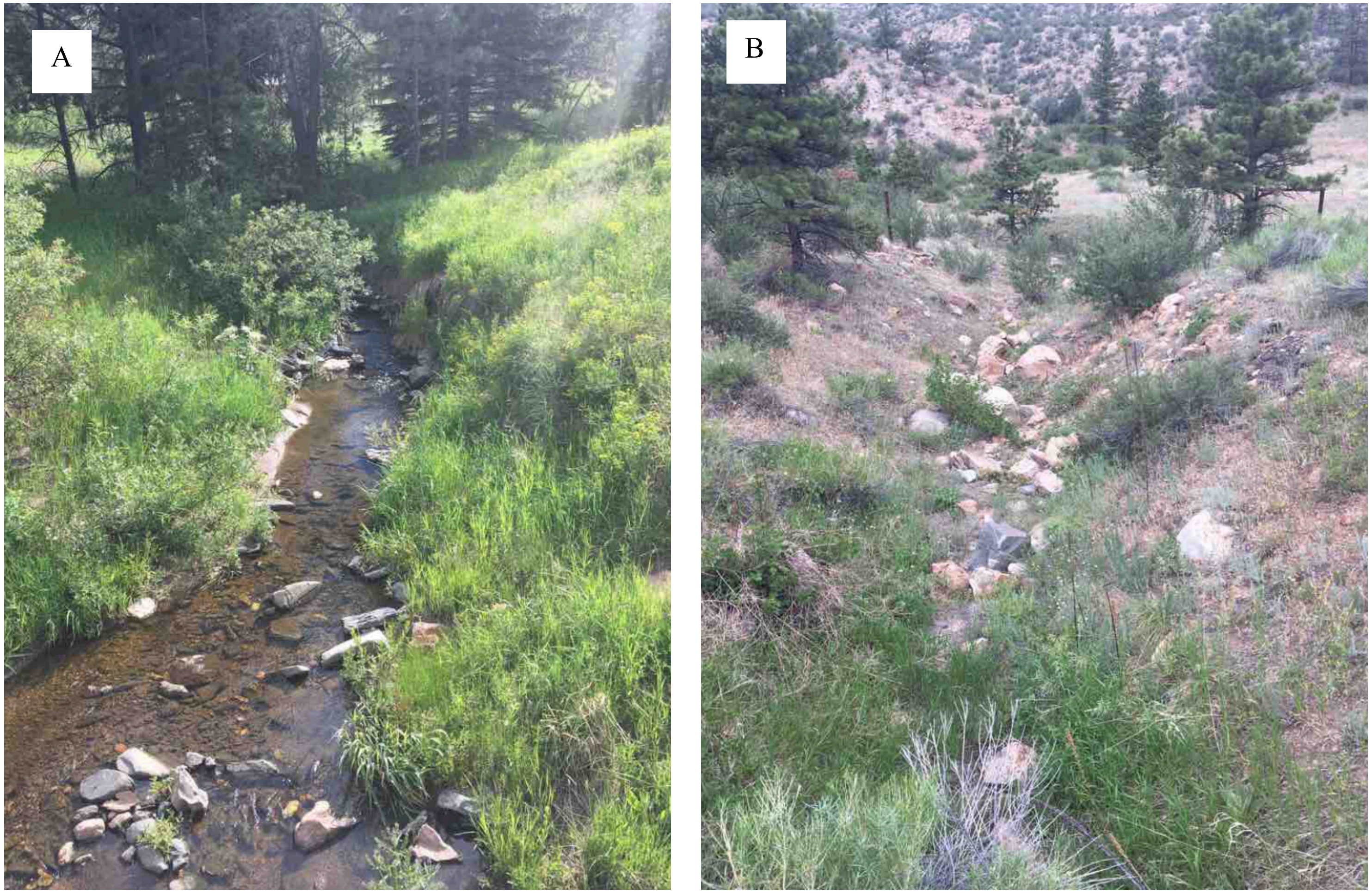

Figure 5.2. Photos taken by Stream Tracker participants showing flow (A) and no flow (B). (CitSci.org, 2017)

Figure 5.3. Maps.me logo. (Maps.me, no date).

Figure 5.4. CitSci.org logo. (CitSci.org, 2017).

Figure 5.5. Stream Tracker diagram explaining how to start stream tracking. (Stream Tracker, 2017).

5.3 Methods

This case study uses three different methods; a survey for Stream Tracker participants, an interview with the Stream Tracker project managers and data quality checks of Stream Tracker data collected by citizen scientists.

5.3.1 Survey

Survey 3 (Appendix 6) was designed specifically for people who have participated in Stream Tracker. A series of 10 multiple choice, Likert-type scale and open questions asked participants to rate their Stream Tracker experience, how likely they are to participate in the future and for how long, and what would increase their interest to participate in the future. Respondents were able, but not required, to leave comments after each closed question.

To recruit participants, survey 3 was sent to students at Colorado State University who had participated in Stream Tracker for extra credits. This guaranteed 12 responses as the students were required to fill in the survey to get the extra credits.

5.3.2 Interviews

An interview with the two project managers of Stream Tracker was conducted (Appendix 7). This technique was chosen because the case study sought to gather rich qualitative information from a limited number of people and desired in-depth information about their experiences. The interview was conducted on FaceTime as it was not possible to meet in person and there was already an established relationship with the project managers. Due to time constraints, the interview was conducted with both project managers at the same time. The interview consisted of structured open questions. Firstly, a few general questions were asked about their main struggles and successes with the project. Then, more focused questions about recruitment and retention were asked. Finally, questions were asked about data quality and how they think the scientific community will receive their data.

The interviews were analysed using content analysis. Each sentence was analysed and coded which revealed themes as in section 3.3.1.

5.3.3 Data Quality Checks

Photos uploaded to CitSci.org by citizen scientists were analysed to validate the accuracy of observations made by citizen scientists. A study by Wiggins *et al.* (2011) found that photo validation was the second most common mechanism for data validation after expert review. Photographing specimens has also been suggested by Crall *et al.* (2011) for checking the accuracy of species identifications. Citizen scientists' photos of streams were analysed alongside their observation of flow, no flow or standing water. Observations were marked as correct if the photo submitted matched the observation e.g. if a photo showed water and the observation said flow. Observations were marked as questionable if the photo did not match the observation e.g. if a photo showed no water and the observation said flow.

5.4 Results and Discussion

5.4.1 Participants Experience

Survey 3 generated 12 responses. All respondents were students from CSU who had participated in Stream Tracker for extra credits. Therefore, these results only provide information about a small group of Stream Tracker participants. Nevertheless, their experiences and comments are still insightful.

11 of the respondents rated their experience as either enjoyable or extremely enjoyable (Figure 5.3). 100% of respondents indicated that they were quite likely, likely or very likely to stream track again (Figure 5.4). However, when asked how far into the future they would stream track 8% said they do not plan to stream track again (Figure 5.5). This highlights a limitation with collecting data using an online survey (discussed in section 6.2). Many participants still indicated that they would participate in the future and the most frequent response was that they would participate for several months (Figure 5.5).

The survey also gathered responses about what would increase interest in participating in the future. Respondents said:

> *"Improve the tutorials available for users to enhance data collection quality and the data collectors time."*

> *"Collecting more data than just the presence of water."*

"If we could see what the data is being used for, links to talks that are given about our results."

These comments give helpful ways the project can improve in the future through better tutorials and being able to collect more data. The final comment also suggests a technique for participant retention.

Figure 5.6. How respondents to survey 3 rated their experience of participating in Stream Tracker.

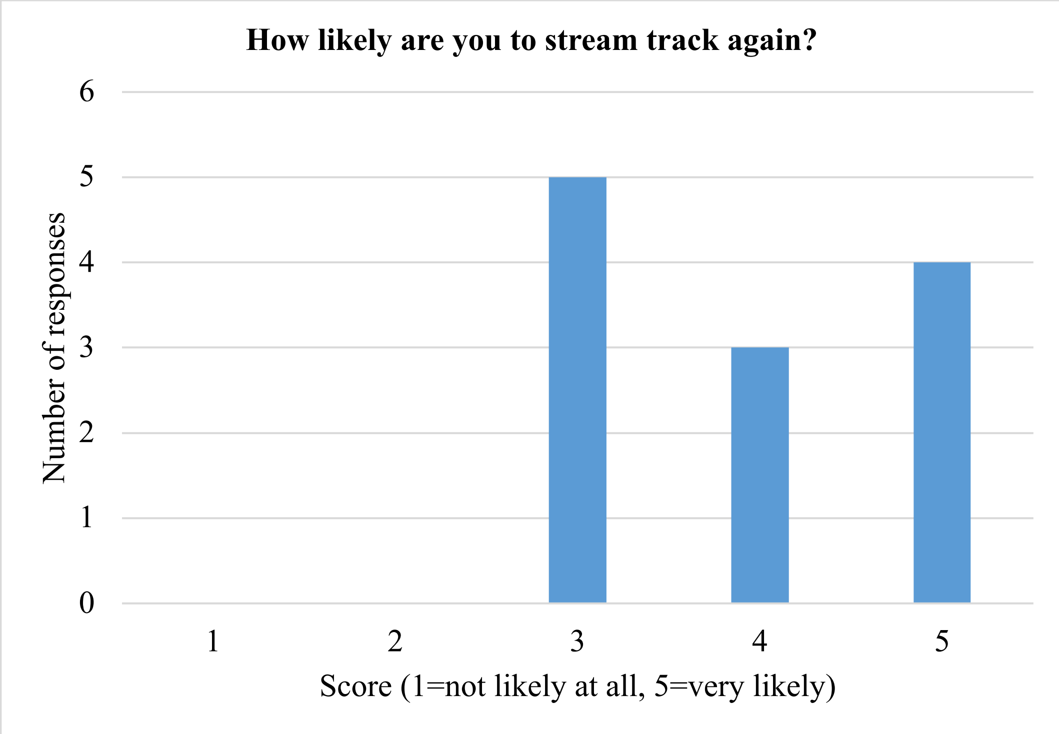

Figure 5.7. How likely respondents to survey 3 are to participate in Stream Tracker again.

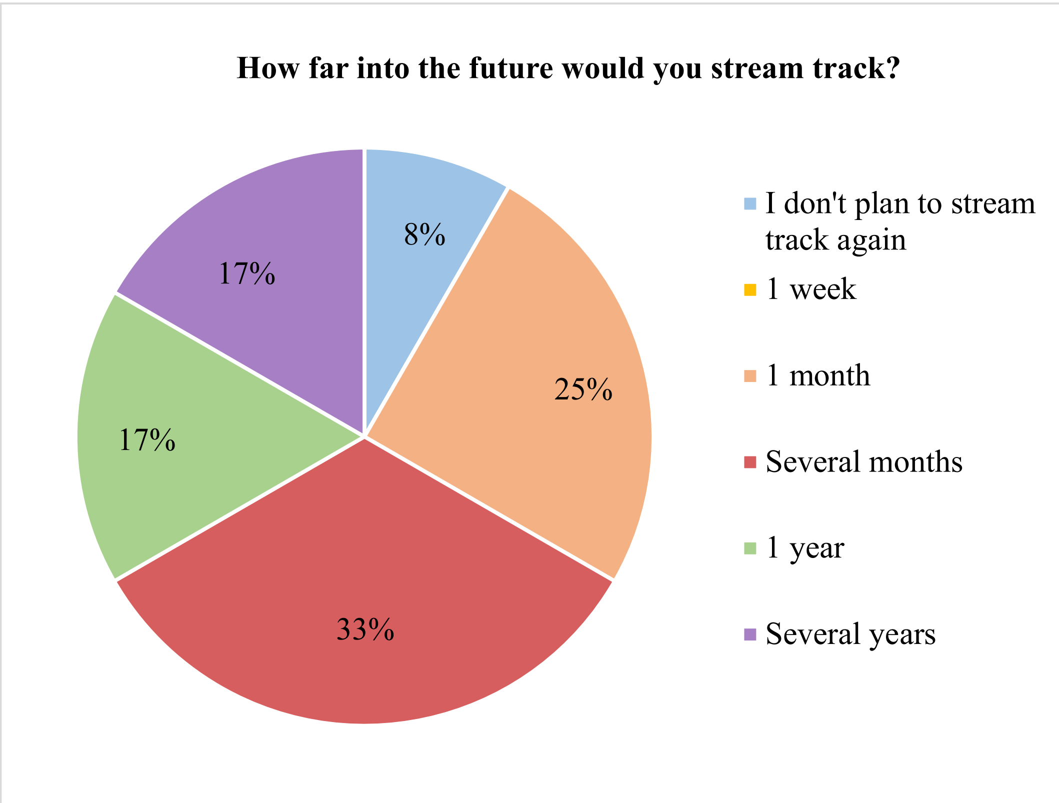

Figure 5.8. How far into the future respondents to survey 3 would participate in Stream Tracker.

The main way the Stream Tracker currently presents data to their participants is through bi-monthly newsletters. In the interview the project managers said they are working with collected data to present it to project members as well as the community. It is hoped that this will serve as a recruitment tool as well as a motivator for current participants to contribute more.

5.4.2 Technology

Technology was a major challenge that was highlighted both in the survey and the interview. In survey 3 participants were asked about their experience of using their mobile phone to stream track. Experiences of using the two apps were mixed but overall not very positive (Figure 5.6). A number of participants commented saying that the mobile app was not working and kept crashing or deleting their data. Others reported that the app was very easy to use and very resourceful. Evidently, the current way of collecting data using mobile phones is not as good as it could be and has reduced the enjoyment of participating for some. This is an issue that needs addressing as Rotman *et al*. (2014) has reported that overly complex technologies create frustration and can cause participants to drop out. This would be damaging to both recruitment and retention of participants.

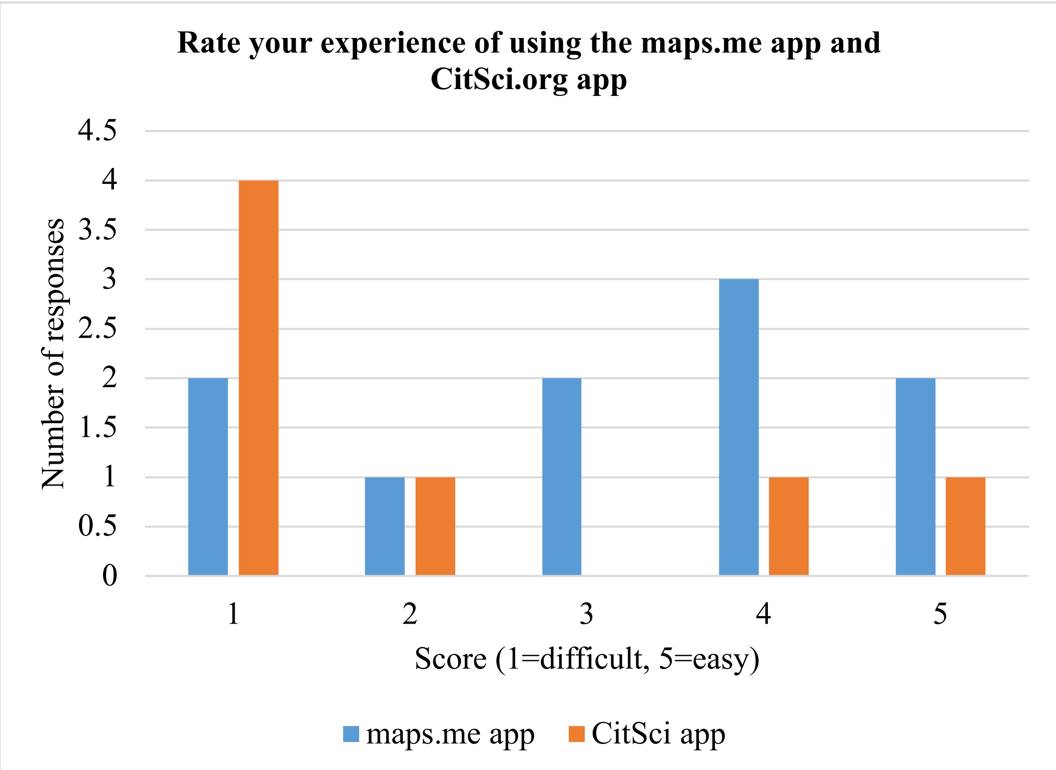

Figure 5.9. How respondents to survey 3 rated their experience of using the maps.me and CitSci.org apps.

75% of respondents to survey 3 indicated that it would be extremely useful to have one Stream Tracker app instead of using both maps.me and CitSci.org (Figure 5.7). Participants commented about a single Stream Tracker app:

> *"Make this happen!"*

> *"This would make it a lot easier."*

> *"Increasing simplicity and ease of use would help."*

> *"I believe more citizens are more likely to enter data correctly with an all in one app and map."*

These comments illustrate that a better, all in one app would be greatly beneficial to the project.

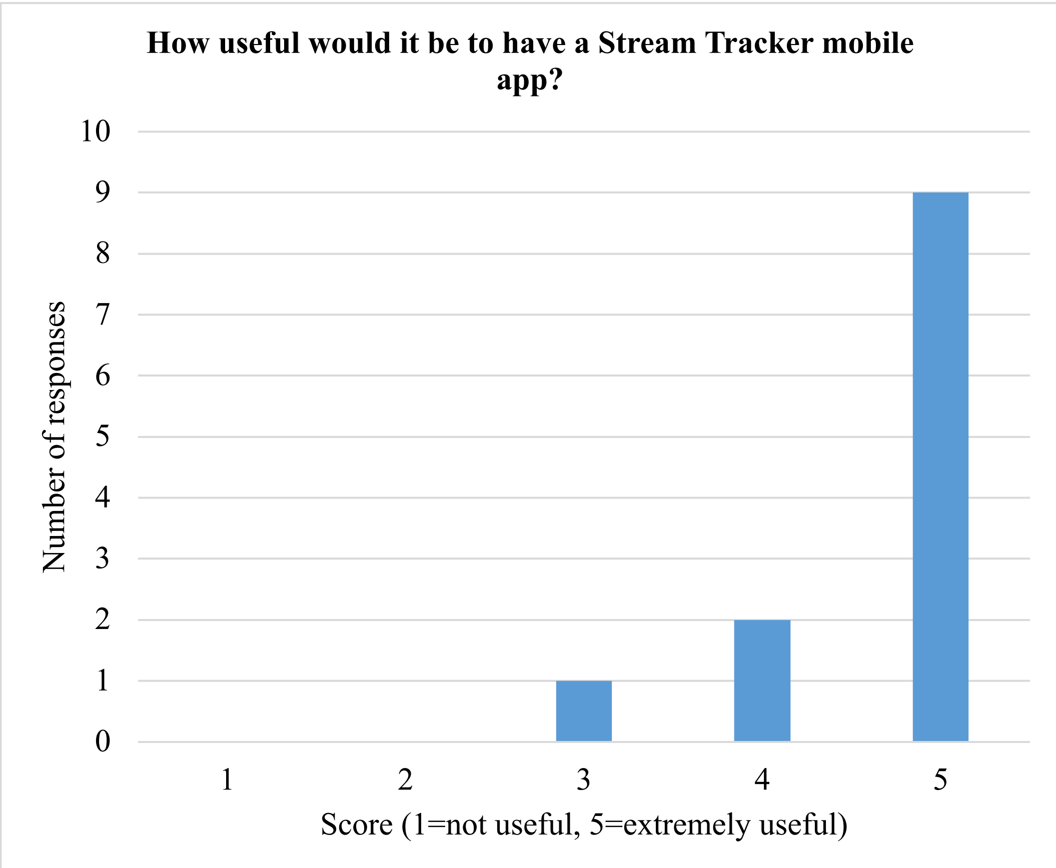

Figure 5.10. How useful respondents to survey 3 think a Stream Tracker app would be.

The interview with the project managers also revealed that technology is one of the main challenges for Stream Tracker:

> *"…on the technology side we want people to be able to use their phones but its challenging to have all that working smoothly."*

> *"…working with mobile applications is a very valuable component of the project but has created the most challenges I think as far as consistency and having a product that people feel familiar with, because they don't think we are quite there yet."*

The survey and the interview have showed that technology is a challenge both for the participants and the project managers. This is a helpful warning to future project managers. It also highlights the importance and necessity of well-functioning, user friendly technology for participant recruitment and retention.

5.4.3 Data Quality

In the interview, the project managers talked about the usefulness of simple data and how keeping data collection simple helps with data quality as well as recruitment.

> *"…we kept data simple enough that quality concerns are not as high…"*

> *"...simple data is the best data especially for getting a lot of people involved…"*

The photo validation data quality check results were mainly positive. 91.45% of the 117 photos and observations analysed proved to be correct (Figure 5.8). The remaining data was questionable because some had recorded no flow but submitted a photo with water obviously in the stream, or the same picture that been uploaded several times for different observations and locations. The first issue could potentially be resolved by improving tutorials and training. The latter issue could be a technological issue which may be solved with a better app. These findings are promising and suggest that citizen scientists can collect high quality data. With some improvements, these statistics may improve even more. However, this method of checking data quality is limited and not well suited for large-scale projects due to the challenges of processing, storing and archiving photos (Wiggins *et al*., 2011).

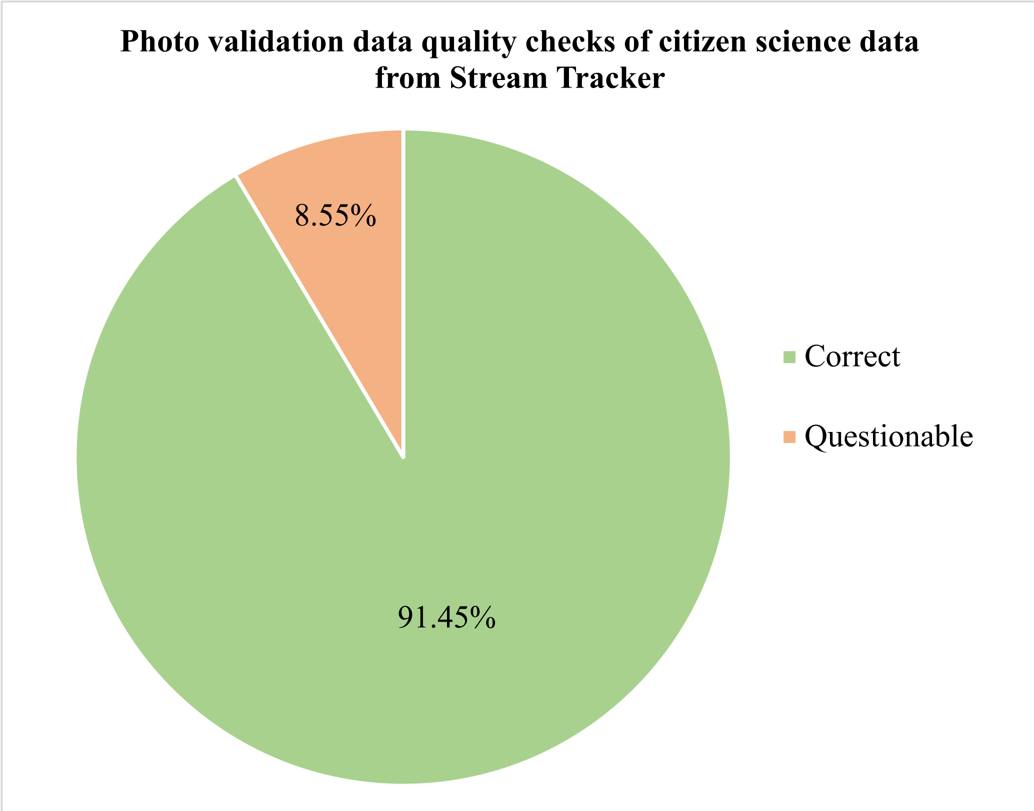

Figure 5.11. Proportion of correct and questionable Stream Tracker observation from citizen scientists after photo validation.

5.5 Conclusion

This chapter has presented a case study on the citizen science project Stream Tracker. The case study consisted of three methods – a survey, an interview and data quality checks – which contributed to research questions 1 and 3. In response to research question 1, the survey results showed that improving tutorials, being able to collect more data and receiving feedback on how the data is being used will help with the retention of participants. Both the survey and the interview revealed that well-functioning, user friendly technology is essential to recruitment and retention. The data quality checks revealed that citizen scientists can collect high quality data on the flow of intermittent streams. This case study has given suggestions from a running citizen science project on how to increase participation and enjoyment of monitoring streams and shown that citizen scientists can successfully collect data on streamflow presence and absence.

Chapter 6: Conclusion

6.1 Key Findings

Citizens' motivations

Research question 1 asked: what motivates citizens to monitor intermittent streams? Results showed that being able to monitor streams whilst doing an existing hobby and knowing it was helping to improve understanding on intermittent streams increased citizens' interest in participating. Location, to contribute to research and having a pre-existing interest in water were the top three motivators. Projects managers should consider this when advertising the project to recruit participants. The case study also revealed that improved training tutorials, being able to collect more data and receiving feedback would help with retention.

Scientists' perceptions

Research question 2 asked: how do scientists perceive citizen science as a way to monitor intermittent streams? Results imply that scientists at CSU will be mostly accepting of citizen science data. Training and design were the two major themes that scientists are concerned about with citizen science. It is the job of the project managers to design projects with adequate training of citizen scientists and scientific data collection methods. Transparency and rigor in these areas is key to scientifically successful projects.

Data quality

Research question 3 asked: how useful is citizen science for producing high quality flow data on intermittent streams? Results from photo validation checks of Stream Tracker data showed that citizen scientists are able to collect high quality data. The questionable observations should be able to be improved with training and advancements in technology.

6.2 Limitations

This study is limited by the use of surveys which do not allow respondents to answer questions at a deeper level. Online surveys also do not allow the researcher to clarify things which can lead to confusion (such as the one that arose in section 5.4.1). Furthermore, the sampling techniques were biased towards citizens associated with nature-based organisations (survey 1), scientists from CSU (survey 2) and student participants of Stream Tracker (survey 3). The sample sizes were also not large enough to draw any conclusions on demographic variations. The interview technique was also limited because it was conducted over the phone rather than in person. Finally, the data quality checks were appropriate for the small number of photos analysed but the technique is time consuming and unsuitable for large-scale projects, which stream monitoring projects are.

6.3 Future Research

Citizens indicated that location was the most important motivation for monitoring intermittent streams. Therefore, project managers would benefit greatly from a study on how much time or how far citizens would be willing to travel to monitoring sites (Alender, 2015).

The most surprising finding from this research is how infrequently the motivation to help the environment appeared compared to the literature. Most previous studies have surveyed volunteer motivations using a set check list. It would be interesting to investigate whether helping the environment is actually a frequent motivator when it is not prompted. This could be done using open question surveys or interviews.

A better understanding of scientists' perceptions could be gained though focus groups. This would enable a deeper discussion on the topic and will allow participants to say much more than they can on an online survey. It would be specifically interesting to investigate whether negative perceptions from the scientific community are actual or only anticipated.

Furthermore, a focus group with Stream Tracker participants would be a much more informative way of gaining feedback on experiences than a survey. A key retention technique is providing participants with feedback on how their data is being used. It is therefore important to ask participants what the best methods of communicating this information would be.

Interesting directions for future research have been raised by this dissertation. Studying citizens' motivations has provided project managers with clear recruitment and retention suggestions. This study has provided an understanding of how scientists might receive citizen science data on intermittent streams and shown the ability citizen scientists have to collect high quality data. It is hoped that this study will be insightful and will help project managers design socially and scientifically successful citizen science projects for monitoring intermittent streams.

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Appendix

Appendix 1. Survey 1.

Citizens Monitoring Colorado's Streams

*Required

This survey is exploring people's interest and motivation to participate in citizen science to monitor small water streams.

Citizen science: the collection and analysis of data relating to the natural world by members of the general public, typically as part of a collaborative project with professional scientists.

1. Which category below includes your age? *

- ◯ Under 18
- ◯ 18-24
- ◯ 25-39
- ◯ 40-59
- ◯ 60 +

2. What is your gender? *

- ◯ Female
- ◯ Male
- ◯ Prefer not to say
- ◯ Other:

3. What is the highest level of education you have completed? *

- ◯ Less than high school degree
- ◯ High school degree or equivalent (e.g. GED)
- ◯ Some college but no degree
- ◯ University degree
- ◯ Post graduate degree

4. What is your employment status? *

- Full time
- Part time
- Unemployed
- Student
- Military
- Retired
- Other: ____________

5. What is your occupation? *

Your answer

6. Have you ever participated in a citizen science project before? *

- Yes
- No

7. If you had the opportunity and available time to participate in a citizen science project to monitor the flow of small streams, how interested would you be in participating? *

	1	2	3	4	5	
Not interested	○	○	○	○	○	Extremely interested

8. What would motivate you to participate in a citizen science project to monitor the flow of small streams? *

Your answer

9. How interested would you be in participating in a citizen science project to monitor the flow of small streams if you could do it using an app on your phone? *

	1	2	3	4	5	
Not interested	○	○	○	○	○	Extremely interested

10. Which of the following activities do you enjoy doing in your spare time? *

- ☐ Hiking
- ☐ Running
- ☐ Biking
- ☐ Horseback riding
- ☐ Going on a road trip

11. All the activities above can be done whilst participating in a citizen science project to monitor the flow of small streams. How interested would you be in participating in the project if you could combine it with one of these activities? *

	1	2	3	4	5	
Not interested	○	○	○	○	○	Extremely interested

12. If participating in a citizen science project to monitor the flow of small streams would increase our understanding of droughts, biodiversity and downstream water quality, how interested would you be in participating? *

	1	2	3	4	5	
Not interested	○	○	○	○	○	Extremely interested

13. Where did you hear about this survey?

Your answer

Thank you.

SUBMIT

Appendix 2. Table breaking down the changes in interest in monitoring intermittent streams demographically for the phone scenario.

Demographics	Decrease	Increase	No change
18-24	1%	2%	5%
25-39	1%	6%	9%
40-59	5%	6%	26%
60+	15%	4%	22%
TOTAL	21%	18%	62%
Female	10%	8%	33%
Male	10%	9%	28%
Prefer not to say	1%	1%	1%
TOTAL	21%	18%	62%
University degree	12%	8%	21%
Post graduate degree	6%	7%	28%
Some university	2%	2%	12%
TOTAL	21%	18%	62%
Full time	5%	9%	26%
Part time	2%	3%	8%
Unemployed	1%	2%	4%
Self employed	1%	0%	0%
Military	0%	0%	1%
Retired	12%	3%	20%
Student	0%	1%	3%
TOTAL	21%	18%	62%

Appendix 3. Table breaking down the changes in interest in monitoring intermittent streams demographically for the activities scenario.

Demographics	Decrease	Increase	No change
18-24	0%	4%	3%
25-39	0%	8%	8%
40-59	1%	8%	28%
60+	8%	2%	30%
TOTAL	9%	21%	69%
Female	5%	10%	36%
Male	5%	11%	32%
Prefer not to say	0%	1%	2%
TOTAL	9%	21%	69%
University degree	5%	11%	26%
Post graduate degree	4%	6%	31%
Some university	1%	4%	12%
TOTAL	9%	21%	69%
Full time	1%	11%	27%
Part time	1%	3%	10%
Unemployed	0%	2%	4%
Self employed	1%	0%	0%
Military	0%	0%	1%
Retired	7%	3%	25%
Student	0%	2%	2%
TOTAL	9%	21%	69%

Appendix 4. Table breaking down the changes in interest in monitoring intermittent streams demographically for the understanding scenario.

Demographics	Decrease	Increase	No change
18-24	0%	4%	3%
25-39	0%	8%	8%
40-59	0%	8%	28%
60+	5%	7%	29%
TOTAL	5%	27%	68%
Female	2%	15%	33%
Male	2%	11%	34%
Prefer not to say	0%	1%	2%
TOTAL	5%	27%	68%
University degree	0%	11%	31%
Post graduate degree	3%	12%	26%
Some university	2%	3%	12%
TOTAL	5%	27%	69%
Full time	0%	12%	27%
Part time	1%	4%	9%
Unemployed	0%	3%	3%
Self employed	0%	0%	1%
Military	0%	0%	1%
Retired	4%	7%	24%
Student	0%	2%	2%
TOTAL	5%	27%	68%

Appendix 5. Survey 2.

Scientists' Perceptions of Citizen Science

*Required

This survey is investigating how scientists perceive citizen science for my dissertation.

Citizen science: the collection and analysis of data relating to the natural world by members of the general public, typically as part of a collaborative project with professional scientists.

1. Which category below includes your age? *

- Under 18
- 18-24
- 25-39
- 40-59
- 60 +

2. What is your gender? *

- Female
- Male
- Prefer not to say
- Other:

3. Which country do you work in? *

- UK
- USA
- Other:

4. What is the highest level of education you have completed? *

- Batchelor's degree (e.g. BA, BS)
- Master's degree (e.g. MA, MS, MEd)
- Professional degree (e.g. MD, DDS, DVM)
- Doctorate (e.g. PhD, EdD)
- Other:

5. What is your primary area of research? *

Your answer

6. To what extent do you think data collected by the public is reliable? *

	1	2	3	4	5	
Completely unreliable	○	○	○	○	○	Totally reliable

Please give a reason for you answer.

Your answer

7. To what extent do you think data collected by the public is accurate? *

	1	2	3	4	5	
Completely unreliable	○	○	○	○	○	Totally reliable

Please give a reason for your answer.

Your answer

8. To what extent are you engaged with citizen science? *

	1	2	3	4	5	
No engagement	○	○	○	○	○	Very engaged

9. Do you think citizen science could be carried out in your area of research? *

- ○ Yes
- ○ No
- ○ Maybe

10. Would you like to engage citizen scientists in your area of research? *

- ○ Yes
- ○ No

Please give a reason for your answer.

Your answer

11. Do you think citizen scientists can collect data comparable in quality to that collected by professionals? *

- ○ Yes
- ○ No

Please give a reason for your answer.

Your answer

12. Do you think data generated by citizen science can be used to publish papers? *

- Yes
- No

Please give a reason for you answer.

Your answer

13. What do you think your peers in the wider scientific community think about citizen science? *

Your answer

14. "Citizen science is good when data is very time consuming to collect." *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

15. "Citizen science is good when data needs collecting at a large geographic scale." *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

16. "Citizen science is good when the data being collected is a simple observation of the presence or absence of something." *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

17. "A citizen science project is a good way to accomplish public outreach." *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Please give a reason for your answer.

Your answer

18. "A citizen science project is a good way to accomplish education." *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Please give a reason for your answer.

Your answer

19. "A citizen science project is a good way to increase public understanding of science and how data is generated." *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Please give a reason for your answer.

Your answer

Thank you for your time.

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Appendix 6. Survey 3.

Stream Tracker Survey

Tell us about your Stream Tracker experience!

*Required

1. Rate your Stream Tracker experience. *

	1	2	3	4	5	
Not enjoyable	○	○	○	○	○	Extremely enjoyable

Any comments?

Your answer

2. Are you likely to stream track again? *

- ○ 1 - Not likely at all
- ○ 2
- ○ 3
- ○ 4
- ○ 5 - Very likely

3. How far into the future would you be committed to stream tracking? *

- ◯ I don't plan to stream track again
- ◯ 1 week
- ◯ 1 month
- ◯ Several months
- ◯ 1 year
- ◯ Several years

4. What would increase your interest in stream tracking in the future? *

Your answer

5. If you used your phone to stream track, what type of phone do you have? *

- ◯ iPhone
- ◯ Android
- ◯ I did not use my phone to stream track
- ◯ Other: ____________________

6. If you used maps.me to navigate Stream Tracker points, rate your experience.

	1	2	3	4	5	
Difficult	◯	◯	◯	◯	◯	Easy

Any comments?

Your answer

7. If you used the CitSci mobile app to collect data, rate your experience.

	1	2	3	4	5	
Difficult	◯	◯	◯	◯	◯	Easy

Any comments?

Your answer

8. How useful would it be to have a Stream Tracker mobile app where you can navigate to points and enter data in the same app? *

	1	2	3	4	5	
Not useful	○	○	○	○	○	Extremely useful

Please comment.

Your answer

9. Do you think using a mobile app is the best way for Stream Tracker to collect data from citizen scientists? *

- ○ Yes
- ○ No

Please give a reason for you answer. *

Your answer

10. Any other suggestions or comments?

Your answer

If you are a WR416 student at Colorado State University please comment your name for grading purposes.

Your answer

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Page 1 of 1

Appendix 7. Important extracts from interview with project managers of Stream Tracker.

Interviewer: And what have your main struggles been?

Interviewee 1: Um. From my perspective I think the biggest struggle has been the learning curve for joining the project and how that's coincided with getting the word out and often times we would connect with someone but the project does not quite to the point where people can feel confident about jumping on board and taking initiative and going out to stream track without additional effort on our side. And train and meet with them in person and get them over the initial learning hump.

Interviewee 2: Yeah and then on the technology side we want people to be able to use their phones but its challenging to have all that working smoothly.

Interviewer: What have your methods to recruit participants been and how successful has that been?

Interviewee 1: Um. We have mainly been taking advantage of connections that existed prior to this project in the community. So reaching out to groups and organisations that um, would be familiar with our work and um, then building from there and um, creating that kind of chain where then they reach out to people they know and so on and so forth.

Interviewee 2: We also have, um, gotten students involved, um, through classes. And um, we have connected with some organisations that want to get younger students involved as well but that hasn't happened yet.

Interviewer: And obviously the project is quite new, but do you have any comments on how the retention of your participants is going so far?

Interviewee 1: Um, I feel like those that have joined the project have logged observations more than once which is really promising for retention. And have also responded well to, um, us talking about changing conditions in the field and, um, going out and checking sites. Um, we've had participants who have specifically gone out and logged points following a rain event. Um, so that to me shows interest beyond just the initial they've tried it, they've stream tracked and we never see them again.

Interviewer: Participants like to know how they are helping researchers and that their data is important; how do you communicate this to your participants?

Interviewee 1: Um, our main way of presenting our data has been through our bi-monthly newsletter, getting that out. And, um, with the data that we've collected over the spring and fall we've been working up further analysis on that and so we'll continue, um, to present that to the project members as well as present it within the community as a recruitment tool where people can kind of see what we've been able to pull from the data. Um, and hopefully that will motivate them to want to contribute more.

Interviewer: What do you think your participants have learned from participating in Stream Tracker?

Interviewee 1: They have learned by participating a little bit more about where their water comes from and how those sources of water change over time and the importance of these intermittent stream channels on the landscape for habitat and then also change from disturbance of just through the seasons and **frozen** lost connection and phone hung up.

Phone reconnected.

Interviewer: I think I missed the last bit there.

Interviewee 1: Um, yeah so that they can use their cell phones to collect data and then I guess the final component is that, um, this project is a way to connect to a larger network. I think people gain a lot from seeing their observations post alongside many others that have visited that same site and get to see the data come together.

Interviewer: What lessons have you learned from the project?

Interviewee 1: Um, that working with mobile applications is a very valuable component of the project but has created the most challenges I think as far as consistency and having a product that people feel familiar with cause they don't think we are quite there yet. Um, we've learned that getting a project off the ground takes time to start to establish the process as well as the connections to the community. And so we have come a long way and within this season as far as establishing all those baseline processes and whose part of the project.

Interviewee 2: Yeah, what else. Um.

Interviewee 1: We've learned that there is a definite need for Stream Tracker in talking to both water professionals and then also community members. Like I mentioned before I think everybody finds an element of the project that resonates with them personally. Whether or not it's a way they could use Stream Tracker to help them collect data that is important to them or use Stream Tracker as a way to connect to places that they are familiar with in a new way.

Interviewer: and then my last question – I've been very interested in how scientists perceive citizen science. How do you think your peers in the wider scientific community will receive your data generated through citizen science.

Interviewee 2: I think they will be excited that the data are there.

Interviewee 1: Yeah, I think the nature of Stream Tracker is that it's producing data that is otherwise exceptionally challenging to collect and so it really comes down to any data is better than no data and we kept the data simple enough that, um, quality concerns are not as high as in other project that collect more intense parameters. And so I think we're generating a really valuable dataset that would otherwise not be obtainable through the more scientific based research studies.

Interviewee 2: I think we've found that some people that work in the profession want us to be collecting more data but, um, from the sort of research scientist side, the fact that we're collecting very simple data makes it more useable because we don't have to worry as *interviewee 1* said about the quality of it as much. And when I say more data I mean people want us to collect stream flow and water chemistry and you know other aspects of streams.

Interviewee 1: But we've definitely confirmed that simple data is the best data especially for getting a lot of people involved I think that we've really honed in on what Stream Tracker is really trying to be as a project and what its not trying to be and that's really helped guide us.