CITIZEN SCIENCE FOR WATER QUALITY MONITORING AND MANAGEMENT IN KWAZULU-NATAL

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ABSTRACT

The citizen science approach has a role to play in the restoration of river health in catchments affected by pollution. Everyone can become involved in monitoring the health of a river, dam, estuary or wetland closest to them. In KwaZulu-Natal, uMngeni and Msunduzi Catchments, voluntary participation in river health initiatives has been adopted by schools, conservancies, NGOs and catchment management forums.

The purpose of the study was to explore the perceptions and experiences of the use of miniSASS, a simplified South African Scoring System (SASS) tool for monitoring river health in uMngeni and Msunduzi Catchments over the past 15 years. A qualitative exploratory and descriptive study was undertaken through semi-structured interviews and documentary analysis. The researcher managed to purposively select a sample of ten participants, mainly the active users of the miniSASS citizen science tool in the identified catchments.

The finding of the study is that miniSASS is perceived and experienced as a valuable community-based educational tool in Msunduzi and uMngeni catchment which has led to local government authorities to respond faster in solving incidents of industrial pollution; address poorly maintained water infrastructure and fix the leaking sewers contaminating freshwater. The study recommends that a further investigation be made on the economic value of citizen science contribution in KwaZulu-Natal since there were indications that it has already benefited some of the accommodation businesses who appreciated the change in the nearby streams.

DECLARATION

I declare that this research report is my own unaided work. It is submitted in partial fulfilment of the requirements for the degree of Master of Management (in the field of Public and Development Management) at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination.

NAME: HLENGIWE CELE

SIGNED:

On this …**31**st .day of March 2015

DEDICATION

I dedicate this work to my husband Bhekisisa, my kids Msizi, Ntando, Nosipho and Zami and my dearest mom Maggie Zibani.

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I thank the almighty god for giving me strength to carry on until the completion of this thesis. In the process of writing this work I witnessed the true meaning of the African isiZulu philosophy "*umuntu ngumuntu ngabantu*", translated as becoming a person through others. I would not have achieved this piece of work without an amazing support of the people I have listed below;

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LIST OF ABBREVIATIONS

AMCOW	African Minister's Council on Water
AU	African Union
CBD	Central Business District
CREW	Custodians of Rare and Endangered Wildflower Programme
DUCT	DUZI uMngeni Conservation Trust
DWA	Department of Water Affairs
DWAF	Department Water Affairs and Forestry
DWS	Department of Water and Sanitation
FAII	Fish Assemblage Integrity Index
ICTs	Information Communication Technologies
IHI	Invertebrate Habitat Integrity
IWRM	Integrated Water Resource Management
IWMI	International Water Management Institute
NAEHMP	National Aquatic Ecosystem Health Monitoring Programme
NEPAD	New Partnership for African Development
NGO	Non – Governmental Organisation
NWRS2	National Water Resource Strategy 2
NASS	Namibia Scoring System
MOMS	Management – Orientated Monitoring System
UEIP	uMngeni Ecological Infrastructure Partnership

UNEP	United Nations Environment Programme
OKAS	Okavango Scoring System
RAM	Rapid Assessment Method
RHP	River Health Programme
SASS	South African Scoring System
WRC	Water Research Commission
WESSA	Wildlife and Environment Society of South Africa
ZISS	Zambia Invertebrate Scoring System

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CHAPTER ONE

INTRODUCTION AND BACKGROUND

1.1 Introduction

Water scarcity is a global phenomenon that is continually drawing the attention of policy makers towards developing strategies for managing this deteriorating resource more efficiently. The United Nations Environment Programme is stressing public participation as the essential part of sustaining the environment to overcome this challenge. Unless public participation is strengthened at local level, South Africa, like many other countries in Africa, will continue to face a bleak future due to pollution of water resources.

Water resources are continually affected by increasing economic development. Most of the impacts causing ecosystems' degradation result from activities such as the general dumping of waste, agricultural activities, industrial pollutants and failing municipal sewers. It has already been pointed out that the population of South Africa will have doubled by 2025, which will eventually lead to severe water challenges, part of which will emanate from poor water quality. As such, South Africa's recently revised National Water Resource Strategy (NWRS2) acknowledges that the country's water resources are not in a healthy state. Out of 223 river ecosystem types, 60 per cent are already threatened, with 25 per cent critically endangered.

The study presented here was conducted in KwaZulu-Natal (KZN), within the uMngeni and Msunduzi catchments, where a citizen science approach was explored as an intervention to solve the water pollution problems. Despite many factors contributing to the contamination of water resources in these catchments, efforts are in place to keep rivers, streams, dams and estuaries pollution-free with the help of voluntary participation from communities.

Citizen science refers to the partnership between scientists and non-scientists in the collection, analysis and sharing of scientific data. However, this research was only confined to the monitoring of water quality in rivers and streams of the Msunduzi and uMngeni catchments.

Over the years researchers have used varying terminology to refer to a citizen science approach. While some refer to community-based monitoring, others refer to 'public participation', and 'volunteer-based monitoring' as well as 'participatory science', depending on the researcher's preference.

The reviewed literature provided insights into the exploration of three types of citizen-based learning processes common in public participatory engagements: contributory projects (citizens contribute to the projects done by scientists); collaborative projects (citizens and scientists collaborate on the scientific projects); and co-created projects (citizen's work done jointly with scientists), with participants at liberty to take distinct leadership positions (Glasser, 2009). As the community members develop their identity, social learning takes place and builds capacity in citizens to drive meaningful change in the environment (Glasser, 2009).

1.2 Background

1.2.1 Policy and legislative framework

The management of water resources is acknowledged in the Constitution (RSA, 1996) holding that all South Africans have a right to be involved in all of the issues affecting their well-being. The notion of cooperative governance for water management is supported by various statutes of the state. Emphasis on public participation is made in the South African Constitution (Ch.3, 4, 10), the National Water Act (No. 36 of 1998), Water Services Act (No. 108 of 1997), National Environmental Management Act (No. 107 of 1998), Municipal Systems Act (No. 32 of 2000) and the Traditional Leadership and Governance Framework Act (No.41 of 2003) (Pollard and Du Toit, 2010).

The National Water Act is based on sound ecological principles, such as that of establishing an 'ecological Reserve', which requires regular monitoring of rivers (Kleynhans, 1999, p.266). By monitoring fish assemblages and the interpretation of information using a specific index, the eco-status of a river becomes known to the public (Kleynhans, 1999, p.266). The National Water Act also recognises the establishment of a national monitoring system, and a sound information system, by the Ministry of Water (Pollard and Du Toit, 2010). However, despite this internationally acclaimed piece of legislation, South Africa still faces a lot of challenges in achieving the intended objectives of the Act. The Act does not prescribe a manual on how to go about managing rivers and streams as economic developments take their toll. Hence, our water resources are left unhealthy or 'sick'.

Based on the National Aquatic Ecosystem Health Monitoring Programme (NAEHMP), and more specifically, the River Health Programme (RHP), the protection of water resources by people closest to them makes sense (Griffin, Palmer and Scherman, 2014). Voluntary participation of citizens in monitoring water resources was raised in Parliament in 2006 by the South African Parliamentary Portfolio Committee on Water Affairs, as a matter of national importance towards addressing the declining state of water quality in rivers (DWAF, 2008). The recommendation of the Committee was the use of people close to the rivers as custodians of water quality since they benefit directly from them. Although this was raised as a matter of urgency, it has not been implemented to the extent that was intended.

In their study Griffin, *et al.*, (2014) argue that provincial agencies are under-capacitated to provide detailed river reports. Citizen science can assist in closing this gap, by generating water resources water quality data if there are organised monitoring points where trained community-based volunteer monitors can assist.

The White Paper on a National Water Policy for South Africa (1997) stressed the need to involve water users and other interested parties in the protection of the water resources, which was firmly established in the Water Resource Classification System (WRC, 2014).

Additionally, the study supports public awareness on water as highlighted in the Department of Water and Sanitation's Water for Growth and Development Framework which stressed the need to raise awareness about water not only for the youth but also the general public (DWAF, 2009).

1.2.2 The scope and context of the study

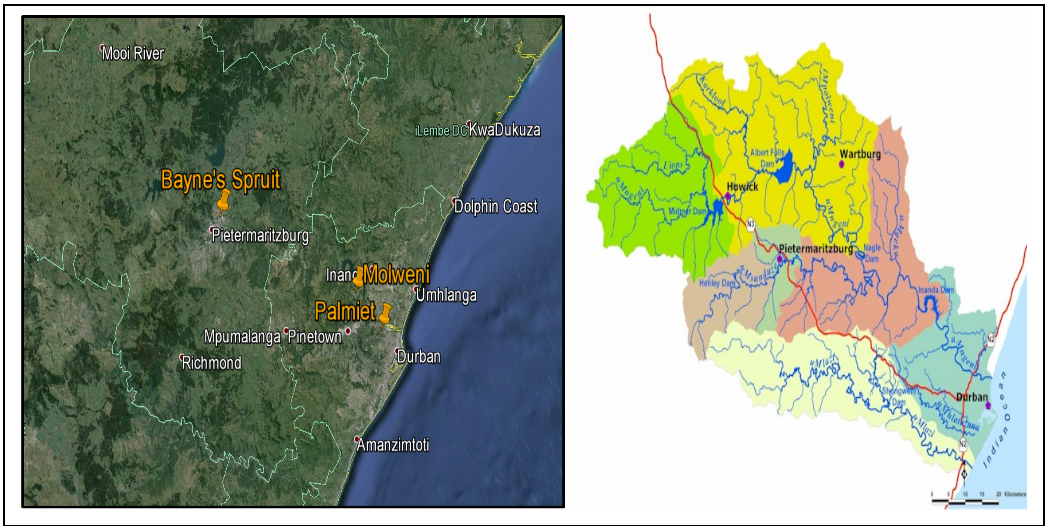
South Africa faces a decline in water quality and quantity in rivers due to population increases and expanding economic activities (Oberholster and Ashton, 2008). There is therefore a need to tackle man-made causes by considering man-made solutions at local level, and to have more 'eyes and ears on the ground' for water resources. If there is a better understanding of how people perceive and experience citizen science tools offered to communities for assessing water quality, there could be improved management of the country's water resources.

This study argues that a participatory approach linked to 'results-driven' intervention in the use of science tools for monitoring river health at a community level brings about sustainability and builds capacity needed to continually fight the environmental problems affecting society at large today. This study, therefore, explores the perceptions and experiences of users of miniSASS, a biomonitoring tool (monitoring water resources using biological organisms) for use by non-scientists in checking water quality, in uMngeni and Msunduzi catchments. The researcher aimed to derive an understanding of how miniSASS, which is one of the citizen science tools, has been used as a biomonitoring tool for rivers and streams in the two catchments over 15 years of river health monitoring, between 1998 and 2013, in KZN.

1.2.3 Study area

As indicated earlier, the study focused on the KZN province and covered Msunduzi and uMngeni catchments as indicated in figure 1 below.

Figure 1: Maps showing the study area which is KZN Province (left) and UMngeni and Msunduzi Catchments (right).



Source: RHP

The area of the uMngeni catchment is 4 416 km^2 and the river length is 265 km from source to mouth (RHP, 2007). The Msunduzi catchment covers an area of 875 km^2 and 115 km tributary length. Both catchments are densely populated with an average of 2 500 people per km^2 and a population density ranging from 5 000 to over 20 000 people per km^2 (RHP, 2007). Although these catchments have conserved natural areas, they are also impacted by intense industrial and urban developments (RHP, 2007). Umgeni Water, the water utility for the region, supplies over one billion litres of potable water to local businesses and households, supplying at least four million people in KZN (DUCT, 2013). Umgeni Water, a local water utility supplying treated drinking water, gets its water from the uMngeni and Msunduzi river catchments (DUCT, 2013). Figure 1 above shows the uMngeni and Msunduzi catchments as the areas of focus in this study.

A study conducted by SRK Consulting (SRK, 2009) indicated that the water quality within the Msunduzi catchment varies significantly between different parts of the catchment. While the upper reaches indicate safe water quality, there is a marked decline as the river passes through Pietermaritzburg and in certain sub-catchments due to pollutants arising from the surrounding settlements (SRK, 2009). The SRK Consulting report further indicated that some sub-catchments were in an unacceptable state needing urgent management actions**.**

Figure 2: Use of miniSASS field guide for assessing water quality

Source: Baynespruit project, 2014

1.3. Problem statement

uMngeni and Msunduzi catchments are currently not in a healthy state. The water quality is affected by industrial pollutants with incidents of raw sewage flowing directly into the streams and exacerbated by the informal settlements along the banks of the rivers with no proper toilet facilities, and general illegal waste disposal from residential areas. Despite all the factors mentioned above, these catchments are known for a prominent water-sport event, the annual Dusi Canoe Marathon, which will be affected if the quality of the water continues to deteriorate.

Citizen science can play a significant role in protecting the catchments by monitoring the rivers and reporting sources of pollution. This approach has gained momentum in Msunduzi and uMngeni catchments; however, data collected through this approach has not paved the way for decision-making within the national river health management structures. In areas where community-based monitoring of water resources is done, there is no opportunity offered to the members of communities to make meaningful contributions towards integrated management and governance of their catchments (Sharpe and Conrad, 2006).

Additionally, ordinary South African citizens barely understand what contributes to the pollution of their rivers and streams; yet they depend on these resources for their well-being. Citizens also have a Constitutional right to live in a healthy environment; therefore, monitoring and reporting water quality from local rivers is key to their well-being (DWA, 2013). Given that in South Africa only 95 per cent of people are served with a piped water supply, the rest must still depend on raw water drawn from streams, springs, wetlands and rivers for their well-being (WRC, 2014). Understanding the basics of water quality in water resources is therefore a need shared by all citizens. Moreover, water quality has been classified as a 'wicked' problem. A wicked problem in the context of this research refers to something that is difficult to solve due to its changing nature and associated contradiction that makes it hard to recognise and creates the need for multiple interventions (Kolbe, 2013).

Water resources management teams need to understand the value of engaging community members in data collection using simple citizen science tools currently in use, such as miniSASS. miniSASS is a simplified scientific tool that uses classes of invertebrates (animals without backbones) to indicate whether a river is healthy or sick (Dickens and Graham, 2002). Invertebrates such as dragonflies, mayflies, crabs, shrimps, water snails, worms, damselflies, leeches, stoneflies and others are able to indicate the general quality of water in rivers (Peddie, 2008). When a river is in a healthy state it will have a wide range of animals and plants (Palmer, Berold, Muller and Scherman, 2002, p.36). miniSASS was therefore developed as a simplified form of SASS by Umgeni Water and Ezemvelo KZN Wildlife, based on the sensitivity of invertebrates to the polluted water (Peddie, 2008, p.59).

Leading researchers in the field of aquatic ecology in South Africa have focused mostly on designing a biomonitoring tool known as the SASS, now in its fifth revision, for use in assessing invertebrate assemblages as an indicator of river health (Dickens and Graham, 2002). When SASS5 was launched in 2012, a simplified version suitable for non-scientists, known as miniSASS, was developed for community-based monitoring of river health. The system uses the composition of invertebrate communities found in rivers based on their sensitivity to water quality (WRC, 2014). Users are supported by field guides, and sampling material such as nets, trays and other simplified equipment, to collect and identify the invertebrates. The Water Research Commission (WRC) (2014, p.154) reported that about 6 000 from environmental assessments following SASS methodology have been examined and that a correlation was found between SASS and miniSASS results. The researcher saw a need to do an investigation on how miniSASS has practically been perceived and experienced in its application within the Umgeni and uMsunduzi catchments in KwaZulu-Natal. The study was also concerned about establishing whether the use of miniSASS has contributed to the improvement of river health as well as people’s consciousness about pollution and the desire to achieve clean water resources in their areas. As noted by Taylor (personal communication, 29 October 2014) we need to be asking ourselves if it is possible to link management practices to miniSASS fieldwork practices.

Dispensing citizen science tools is another mechanism of empowering communities with science knowledge and tools needed for monitoring water quality in their local rivers. Through citizen science interventions, non-scientists are able to report on the status of their local rivers for purposes of efficient management by the designated government institutions. Citizen science is not a new phenomenon as it is commonly used for monitoring biodiversity and environmental data (Tweddle, Roy, Pocock, Preston, Savage and Robinson, 2012). For several decades, scientists have been collaborating with non-scientists in gathering data on climate change events, ecological restoration, water quality monitoring, bird counts, butterfly counts, recording harvest seasons of crops and many other environmental studies (Silvertown, 2009, p.467). Australia and Canada are noted in the literature as having successfully implemented citizen science programmes in monitoring catchments using high-quality water quality testing tools (Conrad and Hilchey, 2011).

There has not been much reported in the literature on water quality monitoring using citizen science approaches. Researchers such as Miller-Rushing, Premack and Bonney (2012) provided a historical overview of citizen science in general and predicted its future while also elaborating on how it has changed over the past 100 years. The current state of citizen science is reviewed thoroughly by Dickinson, Shirk, Bonter, Bonney, Crain, Martin, Phillips, and Purcell (2012). Newman, Wiggins, Crall, Graham, Newman and Crowston (2012), on the other hand, speculate about the future of citizen science while exploring the role of new technological interventions. This study aimed to explore the perceptions and experiences relating to the use of miniSASS, a citizen science tool for river health biomonitoring, in KwaZulu-Natal, over a period of 15 years.

To date, no study has investigated how the use of miniSASS has benefitted its users and clearly, there is no documentation made so far on perceptions and experiences of this citizen science tool. Findings from the uMngeni and Msunduzi exploratory study may help in shedding some light on how miniSASS can be extended to various parts of South Africa in an effort to restore rivers to more pristine conditions.

People living in catchments need to be ‘watchdogs’ of the rivers, streams, dams and wetlands in their areas. The Department of Water Affairs and Forestry’s Strategic Framework for National Water Resource Programme emphasises that the public should be made aware of water resource quality matters as they are in a position to influence decision-making and should be made to participate in the assessment, planning, implementation and evaluation of solutions (DWA, 2004). Additionally, water resources offer recreational opportunities to communities such as hiking, canoeing and camping. In areas where water is naturally clean people are able to fish, swim, picnic and have fun (Palmer, *et al*., 2002, p.38). Subsistence fishing is an alternative source of food to some poorer communities residing near rivers (Palmer, *et al*., 2002, p.37).

While involving communities in environmental management helps communities in understanding the environment, it also offers an opportunity to give them a 'voice' on water governance (Kolbe, 2013).

The work done through citizen science in river health monitoring in South Africa has not received much recognition by the concerned government departments, i.e. Water and Sanitation, and Environmental Affairs, as yet, even though it has shown potential to contribute to informed decision-making. Although citizen science has done much for river health monitoring in KZN, there has not been any proper use of the data collected in supporting these Departments' governance structures (DWAF, 2004). This study considers the value of equipping communities with environmental knowledge, building local capacities to tackle the abuse of rivers and streams, and also empowering citizens as 'watchdogs' for their local rivers and streams.

In South Africa, government institutions alone may not succeed in fighting pollution in rivers, dams, streams and wetlands, without engaging people that are affected by this problem. Hence, this study argues that man-made pollution in rivers needs man-made interventions. Studies have shown that due to budget cuts government cannot monitor all of the catchments; support is needed from communities to successfully address the areas needing urgent intervention (Sharpe and Conrad, 2006). The National

Water Act stresses that people living in a catchment should have knowledge about the Ecological Reserve, which emphasises the amount of water in a riverine system, the quality of water and the chemical concentrations in that water, to allow for the functioning of a healthy ecosystem (Palmer, *et al*., 2002).

For effective water management to take place, data collected from water resources must be accurate, reliable and well-organised to inform decision-making (Pollard and Du Toit, 2010). It has been pointed out in the literature that citizen science water data is usually poorly collected and cannot be used in national monitoring programmes (Aronson, Milton and Blignaut, 2007). South Africa, like many other developing countries, suffers from inadequate water quality data, hindering the planning process at governance level. The Department of Water and Sanitation has acknowledged that there is an urgent need for a well-designed, coordinated and managed programme for collecting, assessing and disseminating data on water that is recorded by all entities in the water sector (DWA, 2013, p.67). Water resources data collected through citizen participation could play a significant role in addressing pollution challenges currently degrading our rivers and streams.

1.4 Research purpose

The purpose of this study was to explore the perceptions and experiences of the users of miniSASS in the Msunduzi and uMngeni catchments. Over the past 15 years, the province of KwaZulu-Natal has been at the forefront of working with community groups in river health projects. miniSASS has widely been used as part of river health programmes championed by local NGOs WESSA and DUCT with support from an environmental consulting firm, GroundTruth. The researcher intended to follow an exploratory and descriptive study on cases of miniSASS use, such as conservancies, schools, enviro-clubs, civil society groups, community forums, NGOs and scientists, who have used miniSASS as an indicator of river health in local rivers and streams.

1.5 Research questions

The study attempted to answer the main question, "How has miniSASS been perceived and experienced as a citizen science tool in uMngeni and Msunduzi catchments?" Clarity was further sought by posing complementary research questions as follows;

- What has happened over the past 15 years to improve the conditions of river health in KwaZulu-Natal within uMngeni and Msunduzi catchments?
- How has miniSASS assisted in improving the governance and management of water resources in KwaZulu-Natal?
- How has the integration of technology-based monitoring tools for water resources enhanced citizen participation in river health monitoring and management in KwaZulu-Natal?

1.6 Research objectives

The study was conducted to achieve the following objectives;

- To establish if the miniSASS users experience it as a useful and valuable tool for monitoring river health in the uMngeni and Msunduzi catchments in KZN.
- To establish if there have been any levels of improvement in the governance and management of water resources with the involvement of community-based structures in biomonitoring in Msunduzi and uMngeni catchments.
- To gather insights that can guide the development of management plans involving citizen science inclusion in catchments.

- To establish if technology use provides any improvement of river health in uMngeni and Msunduzi catchments.

1.7 Significance of research

The literature revealed that the perceptions and experiences on the use of miniSASS have not been explored before in KZN and, more specifically, within the uMngeni and Msunduzi catchments. Understanding this perspective is important for water resources managers to make informed decisions on the inclusion of a citizen science approach in their plans. Water resource planners and decision makers for various troubled catchments in South Africa may draw some lessons from the experiences of the two catchments in this report. Additionally, water scarcity is a challenge requiring multidisciplinary approaches in South Africa as a whole.

1.8 Scope and nature of the research

The study focuses on three case studies where miniSASS has regularly been applied to monitor water quality. Citizen science case studies pursued in the study were Molweni School's River Health Project, Palmiet River Watch and the Baynespruit Rehabilitation Project. One of the areas of concern addressed in these case studies was, amongst others, the use of citizen science data to bring about change in water resource management. The researcher explored how citizen science is viewed, specifically by the users of a community-based science tool for water quality monitoring, and to check whether the findings do give users a voice to create meaningful change in their catchments.

The timeframe chosen by the researcher was purposefully structured to include all of the river health activities that may have occurred in the past 15 years in the two catchments. In order to get rich data, the documents on voluntary participation of citizens in these catchments were reviewed prior to the interviews.

1.9. Structure of report

Chapter One: Introduction and background

This chapter provides an overview of the study, including an introduction and background to the study. This chapter also presents the research problem, research questions, purpose statement and the definition of concepts.

Chapter Two: Literature review

This chapter provides the conceptual framework for the study by highlighting the citizen science literature as a basis for research. A lot of arguments about a citizen science approach have been raised in the literature. The literature informed the questions that arose in this study and helped the researcher to develop an argument for citizen science approach for river health monitoring.

Chapter Three: Research methodology

This chapter presents the adopted research approach, research design and the overall process followed in the collection of data. The qualitative methodology adopted to gather the data required to analyse and conclude the findings is defined in Chapter Three.

Chapter Four: Presentation of findings

This chapter provides the research results and data analysis. The chapter presents results, gives clarity on data analysis and concludes with a summary of the research findings.

Chapter Five: Presentation of findings

This chapter gives the conclusions drawn from the study. In this chapter the researcher also makes some recommendations for follow-up research.

Chapter Six: Conclusion and recommendations

The chapter provides an extended summary of the key findings and gives final recommendations for further research.

1.10. Summary

In this chapter I presented the focus area of this study and explained the citizen science approach and its role in the context of South African water policies and legislation. I explained the research purpose, questions and the scope and context of the study. I concluded the chapter by presenting the outline of the preceding chapters in this report.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The literature review presented in this chapter gives a clearer understanding of citizen science as a key concept and focus of this study and the associated benefits for monitoring water quality. The literature provides a background to citizen science and introduces biomonitoring using the South African Scoring System (SASS) and miniSASS. The chapter presents different views of other researchers in relation to the challenges of using a citizen science approach. The chapter further highlights examples where successes and failures in citizen science have emerged.

2.2. Water scarcity in a global context

Water scarcity is a global phenomenon. With the increase in water stress there has been a need to adopt new approaches to manage resources in a holistic manner (UNEP, 2008). The Rio+10 and Dublin conferences have already emphasised the need for water resources protection as being of utmost importance (UNEP, 2008). The emphasis of protection of water resources hinges on the pillars of sustainability, stakeholder engagement, self-reliance, public participation and working towards a healthy environment (Ashton, 2008). Globally, the trend in water resource management is to move beyond just raising awareness to public involvement in understanding water and in decision making. Dickinson, *et al.,* (2012) point out that citizen science projects have now become necessary to address the current environmental challenges. Nowadays, citizen science has evolved towards more advanced technological applications that are easily used by non-technical people (Dickinson, *et al*., 2012, p. 294).

In Africa, water scarcity in many river basins affects economic growth and social development patterns (UNEP, 2008). Water scarcity has made it necessary that development takes place within an Integrated Water Resource Management (IWRM) context. The UNEP project entitled 'Vulnerability Assessment of Water Resources to Change in Africa' was launched in 2003, highlighting the vulnerability of western Indian Ocean island states, and eastern, central, western and northern African regions (UNEP, 2008, p.1). Additionally, the World Summit on Sustainable Development held in Johannesburg in 2002 led the commitment of world leaders to sustainable development (UNEP, 2008), as outlined in the Rio Declaration of 1992 and also the advancement of the Millennium Development Goals of 2000. Water occupies a central role in the development agenda of all of these countries. Equipping communities with easy-to-use science tools helps address the water problem and takes one step towards addressing the water quality challenge at local level.

2.3 Climate change

Southern African countries depend largely on natural resources in the form of agriculture, mining, industry and tourism (UNEP, 2008). Due to their lower levels of development, these countries are vulnerable to climate change impacts (Schulze, 2001), which require citizen participation to be managed efficiently. There is a high level of uncertainty of continuous water supply on the African continent and particularly within southern Africa; due to the impact climate change has on water resources. While South Africa faces the risk of variable climatic conditions, it has been pointed out in research reports that this challenge will in future be bigger, due to lack of preparedness to deal with its impacts at community level (Hughes, Mantel and Slaughter, 2013). While presenting the tools to understand stream ecology through citizen science, a body of water knowledge made accessible to local communities becomes valuable as capacity building for tackling these challenges.

2.4 Water quality challenge

As indicated earlier, water quality is a ‘wicked’ problem in South Africa. Oberholster and Ashton (2008) have pointed out that South Africa is challenged by its geographic location of metropolitan areas in the watersheds of major river catchments. This situation places a heavy burden on the rivers as they carry a lot of waste material from the metros, taking it downstream. Many of the rivers have high concentrations of *E.coli*, chemical and microbial contaminants, salinity, radioactivity, and toxicity, and high levels of sediment and eutrophication, mostly due to human-induced impacts (B. Madikizela, personal communication, 17 October 2014).

Water quality changes over time depending on land-use activities that exist within catchments. For example, when crop farmers use chemicals such as pesticides, fungicides and insecticides they eventually get washed into the rivers causing contamination of water (Griffin, Palmer and Scherman, 2014). In some cases water quality changes because of industrial effluents, sewage effluents, poorly managed urban settlements, and uncontrolled waste disposal (Griffin, *et al.*, 2014). Towns and urban settlements with poor sewage systems discharge untreated effluents into the rivers (Palmer, *et al*., 2002). On the other hand, settlements with pit toilets may contaminate water quality in rivers through what is known as ‘seepage’. As noted by Palmer, *et al.,* (2002), rivers eventually fail to clean themselves when they are overloaded with sewage effluents.

When using citizen science tools the aim is to empower community members with knowledge to understand the basics of water quality and general stream ecology. Local residents are in a better position to understand the sources of pollution, as they are ‘eyes and ears’ on the ground and to tackle the causes (Taylor, 2014). Generally, the quality of water is measured by looking at the physical characteristics such as turbidity and suspended solids, chemical characteristics such as pH and dissolved oxygen, microbiological contents and nutrient enrichment (B. Madikizela, personal communication, 17 October 2014). However, biomonitoring alone cannot guarantee water quality for drinking purposes but sheds some light and helps in raising a 'red flag' indicator about what is going on in the stream (Graham, 2014). For assessing water quality for drinking purposes, the DWS has prescribed standards that must be complied with, e.g., permissible ranges for pH, TDS, fluoride, magnesium, sulphate, chloride, sodium and potassium (DWAF, 2002). Water for irrigation also follows prescribed standards that must be met for water to be discharged (DWAF, 2002)

This study focuses on biomonitoring tools using biological indicators, studying organisms that thrive in rivers where they are attracted by nutrients, or the absence of organisms due to existing pollutants (Graham, Dickens and Taylor, 2003). Citizen science tools help to mobilise communities in voluntary participation in the sustainability of freshwater resources through continuous assessment of rivers and streams even in the absence of scientists.

In Canada, Nova Scotia catchment community groups conduct water quality monitoring activities in more than 10 catchments (Sharpe and Conrad, 2006, p.399). Each group checks the parameters of biological indicators (benthic invertebrates, faecal coliform bacteria), physical indicators (e.g. total suspended solids, temperature), and chemical indicators (e.g. dissolved oxygen, nitrates and pH (Sharpe and Conrad, 2006, p.399).

SASS is a proudly South African tool which is regarded as the backbone to the River Health Programme (RHP) (Dickens and Graham, 2002). By drawing a sample of macro- invertebrates from a flowing river, one can actually check (using the field guide) which species or groups are present which indicate how healthy or 'sick' the water is (See figure 3 below).

Dickens and Graham (2002) have argued that other forms of monitoring, for example, chemical monitoring, may not be sufficient in providing the required data for monitoring water resources. Subsequent to the development of SASS, miniSASS was introduced with a reduced taxonomic complexity, using only 19 macro-invertebrate groups. miniSASS provides a reliable scientifically-proven water quality indicator (Graham, Dickens and Taylor, 2003). As part of South Africa's river monitoring initiatives, SASS has been in place to support the DWS's RHP since its inception in 1995. miniSASS was finally launched in 2000 (WRC, 2014). Palmer, *et al.,* (2002, pp. 26-27) have classified river health into categories as indicated in the Table 1 below.

Table 1: Indication of river health categories

River status	Characteristics
Natural	Unused rivers except for nature conservation, has low impact and offer best services of biodiversity, can be used for spiritual renewal and religious ceremonies.
Good	A river is classified as good if it offers nature conservation, water and waste disposal, has opportunities for ecotourism and beauty.
Fair	A river is classified as fair if it has high levels of water supply and high waste disposal use.
Poor	If the river is over-used with low capacity to provide services in the long term.

Source: Palmer, *et al.,* 2002.pp.26-27)

Figure 3: miniSASS workshop, Pietermaritzburg

Source: GroundTruth and WESSA (2013)

2.5 Definition of citizen science

Citizen science is defined by Araya, Schmiedel and Von Witt (2009, p.11) as the use of science tools by lay people with no formal training on the subject under investigation, and usually resident in the vicinity of research sites where they are trained to carry out science-related data collection. Citizen science emphasises the mutual collaboration between scientists and non-scientists, mostly on a voluntary basis, in the collection of data while building local capacity, creating awareness, fostering education and bringing change in the management of water resources (Taylor and Graham, 2010). Amongst the successful citizen science projects, the Custodians of Rare and Endangered Wildflower Programme (CREW) formed a network of eco-club volunteers in 2003 to help in the conservation of threatened plants and habitats in the Cape Floristic Region (Araya, *et al.,* 2009, p.12). The project involved local plant activists and was expanded to other biodiversity hotspots such as Succulent Karoo, Maputoland and Albany. Araya, *et al.,* (2009, p.12) further cite another example of a citizen science project involving people from disadvantaged backgrounds who provided data to the 'para-ecologist programme' researchers specialising in climate change and biodiversity, and based in Namibia and South Africa. Lastly, involving community members in taking care of the local rivers turns around river health in catchments and provides knowledge to people who are always ready to address problems as they emerge.

2.6 Monitoring natural resources in Africa

Water bodies in southern Africa face many challenges. As noted by Peddie (2008, p. 68), estuaries are mostly affected by siltation, wetlands are disappearing and some perennial rivers are drying up while lakes and dams are polluted. Catchments face prolonged growth of alien invasive plants such as black wattle, pine and eucalyptus (Peddie, 2008, p. 69). Citizen science has a role to play in identifying these problems once knowledge has been acquired by communities.

African countries have been using freshwater macro-invertebrate families for biomonitoring processes suitable to their environmental conditions for many years now. Other than SASS5 that is currently used in South Africa, other water quality monitoring tools such as Namibia's Scoring System (NASS), the Okavango Assessment System (OKAS) in Botswana, and the Zambia Invertebrate Scoring System (ZISS) are being used (Elias, Ijumba and Mamboya, 2014).

Other African countries are also using the Management-Orientated Monitoring System (MOMS) as a community-based tool for monitoring natural resources and, more specifically, in improving management (Mulale and Pelane, 2013). In Botswana, in Senkuyo Village in the Okavango Delta, Ngamiland District, community members were trained in monitoring the community's adherence to hunting procedures, in order to avoid the killing of more animals (Mulale and Pelane, 2013). In the same project, community members were trained on how to record data using pocket books in yellow, blue and red colours for recording various kinds of data.

A study commissioned by the International Water Management Institute (IWMI) (Zemadim, McCartney, Langan, and Sharma, 2013) highlights the successes and challenges encountered when establishing community-based monitoring networks in the three watersheds of Miziwa, Meja and Dapo in the Blue Nile River Basin, Ethiopia. Within these watersheds, community members were trained to monitor streamflow, overland flows, sediment load, shallow and deep groundwater bodies (Zemadim, *et al.,* 2013). Although some success stories are noted in the formation of networks, in Bergville, Potshini, located in uKhahlamba Local Municipality in KZN, there have also been some failures. Two of the three selected farmers could not consistently record data due to their involvement in other farming initiatives (Zemadim, *et al.,* 2013). Other challenges reported in hydrological monitoring systems include theft, vandalism, post-installation damage due to floods, and policy barriers that hinder the implementation of the system (Zemadim, *et al.,* 2013). River health monitoring using biomonitoring tools such as miniSASS in a catchment empowers communities with water science knowledge that helps them to trace and understand the causes of pollution. The science knowledge stays with them for a very long time and presents an opportunity for transfer of knowledge from one generation to the other.

2.7 Monitoring water resources in South Africa

Data plays an important part in the management of water resources. Without accurate data on quality and quantity of water, it is impossible for the water resources authorities to estimate the supply needed for different uses. In South Africa, data on water resource quality is generated through, amongst others, the RHP, which has different designated monitoring points used by the department (Respondent I, 30 January 2015). Each province has accredited water quality monitoring teams that do assessments using indices such as SASS, Invertebrate Habitat Assessment System (IHAS), Fish Assemblage Integrity Index

(FAII) and Geomorphology Index (GI) (interview, Respondent I, 30 January, 2015).

As noted by Taylor (2004), water quality testing is expensive, with lengthy procedures that must be followed to ultimately generate data. SASS users need to identify up to 90 aquatic invertebrate groups to generate data (Graham, *et al.,* 2004). The citizen science tool, miniSASS, requires the identification of only 19 invertebrate groups but produces scientifically reliable data equivalent to SASS results. These methods rely on what is called biological monitoring or assessment of water quality which basically refers to the assessment and interpretation of biological information based on the invertebrates to indicate water quality (Dallas, 2007).

Citizen science, therefore, has a role to play in strengthening the monitoring of water quality in South African catchments, because macro-invertebrates are, firstly, easy to collect and analyse and, secondly, they are explainable to the general public (Cairns and Pratt, 1993, p.10).

2.8 Benefits of citizen science

Participatory monitoring excites citizens. After undergoing training, the volunteers submit data to a central point that would, under normal circumstances, cost scientists a lot of time and money to collect for the country's watersheds. As Graham, (personal communication, 29 September 2014) argues: if citizens are involved in data collection for monitoring water resources, it may become easier for water managers to use a finite number of officers with finite resources. When applying the citizen science approach, residents are able to use local knowledge to put pressure on the planners and decision makers to act on the identified problems (Corburn, 2003). The empowerment of citizens with knowledge and the adoption of critical thinking skills relating to the environment becomes the end result of most citizen science projects, as noted by

Dickinson, *et al.,* (2012) and Graham (2014). Furthermore, Conrad and Hilchey (2011, p.280) highlight the advantage of making science more accessible to the public by increasing scientific literacy, citizen inclusion in local issues and upliftment of scientific literacy. Citizen science projects benefit communities, create an opportunity for understanding their environment better and, most importantly, empower citizens so that they are likely to continue redesigning their own projects even in the absence of researchers (Dickinson, *et al*., 2012).

Figure 4: School learners doing miniSASS in Moreletaspruit

Source: own, 2014

2.9 Challenges relating to citizen science

While there are numerous benefits relating to the use of citizen science, some challenges have also been noted. Monitoring is concerned with presenting accurate, complete and consistent data, which makes it reliable and valid. It has been pointed out that data collected by community groups is hardly used and not even taken seriously by decision makers due to a lack of credibility resulting from poor sampling procedures (Conrad and Hilchey, 2011). In most cases citizen groups involved in collecting data often do not get a chance to meet with the decision makers (Conrad and Hilchey, 2011, p.281). Cooper, *et al*., (2007) argue that the implementation of citizen science projects requires institutional capacity that is centrally located for data collection. Cooper, *et al.,* (2007) further recommend that informatics infrastructure, standardised reporting mechanisms and archiving schemes be considered by data-collecting institutions. However, the existence of a central data management point may not be of help if data collection is not made explicit and guided by some form of data-collection protocol. Data collection by citizens should also allow for feedback to the collectors so that there is a continuous supply of data (Silvertown, 2009).

In 1994, the South African Department of Water Affairs and Forestry (DWAF) launched the River Health Programme Implementation 'Vision 2005 Report' stating that all monitoring programmes should produce data that is verifiable, accurate, complete, economical, reliable, relevant, simple, timely and 'scientifically and managerially' relevant (DWAF,1994). For this to happen, thorough training and allocation of required resources to carry out this monitoring at community level is also important. On the other hand, the screening of data is important to the institution doing water resource monitoring.

Conrad and Hilchey (2011) argue that citizen science data does not get used in decision making structures; citizen science data is not published in peer-reviewed scientific journals. Conrad and Hilchey further suggest that scientists must be involved in providing thorough training that makes validity in data collection less of a problem. WESSA and GroundTruth, through the Eco-schools programme, have been instrumental in training schools and community members on the use of miniSASS. Figure 3 below illustrates how communities were actively collecting data in the uMngeni River.

Figure 5: miniSASS sampling in Pietermaritzburg

Source, GroundTruth, 2014

The retention of experienced participants is mentioned as one of the factors that contribute to proper leadership in quality data collection (Cooper, *et al*., 2007). The challenge of unsustainable and inconsistent projects in most developing countries is pointed out by Araya, *et al*., (2009). Participatory monitoring is a volunteer-based approach with no incentives to encourage continuity amongst community members. The issue of partnership with communities has not been well addressed to solve the current ecology challenges. Hence, Rogers (2008) argues that a lot of scientific products with intrinsic value have been developed and can only be used through science and management partnerships. Government institutions have in the past failed to sustain public interest in doing science for society, such that most projects have lacked prioritisation and implementation (Dickinson, *et al*., 2012).

2.10 Citizen science and technology-based interventions

Nowadays, science data collection is no longer bound to any physical location as technologies have allowed for unlimited cross-border connections. Residents anywhere in the world are now enabled by existing information communication technologies (ICTs) to interact and share data across boundaries. 'Crowd sourcing' has become increasingly recognised within the science sectors as a meaningful tool for innovation. For example, mobile phones are tools commonly used by citizens to voluntarily report real-time data directly to radio stations and television centres. Recently, text messaging using cell-phones has been considered for strengthening campaigns for government elections. US President Obama's election is one such example. In Kenya, for instance, Ushahidi used text messages posted on their website to report incidences of violence, and generated over 45 000 real-time reports (Rivett, Taylor, Chair, Forle, Mrwebi, Van Berle and Chigoma, 2013). In 2013, the City of Tshwane, in collaboration with IBM, launched the IBMWaterwatchers project as a crowdsourcing sewage leakage monitoring tool (J. Taylor, personal communication, 2014). The advantage of using new geospatial technologies is that they include Internet-based applications that can also provide some entertainment to the users while learning about the environment (Dickinson, *et al.,* 2012). It is therefore fitting for this project to look at how technology integration in the monitoring of water resources by community members can improve the management of catchments given the plethora of emerging ICT applications.

Wire sensor networks and online computer video gaming tools are increasingly becoming popular in research circles (Newman, *et al*., 2012). With these technologies the frontiers of ecological research have expanded. Web-based data capturing has revolutionised the manner in which data is captured. Real-time web-based data capturing using Google Maps is becoming increasingly popular and changes the manner in which data is shared (Tweddle, *et al*., 2012).

The advantage of citizen science is its openness to any kind of innovation that could be designed to suit community members. Social media has revealed the potential to change the way traditional monitoring of water resources has been done. Community members can easily be trained on how to engage using networks such as Twitter, Facebook, YouTube and others. Moreover, the miniSASS geospatial website (www.minisass.org) was developed to allow whoever is interested to upload results for any river that is being monitored and to share data at any given point (Graham, *et al.,* 2014). Figure 6 below shows the miniSASS data collectors uploading results from the uMngeni River during a workshop held in Howick, KwaZulu-Natal. Tweddle, *et al.,* (2012) warn that designers of citizen science projects need to cater for online data submission in their design.

Figure 6: Group capturing data on the miniSASS Google Earth website

Source, WESSA, 2014

2.11 Citizen science and social learning

Citizen science renders an opportunity for social learning and transformation. Any factors constraining the occurrence of social learning could further constrain natural resource management (Wenger, 2009). When participants come together in sharing ideas on the management of the environment, the learning process leads to the production of group identity and collective meaning-making. The study reported on here explores how communities embrace or reject community-based science tools for river health as they engage with scientists. Amongst many other factors hindering meaningful learning, the transfer of science knowledge needs to be imparted in a manner that allows participants to understand and to be in a position to change their worldviews. Boakye and Akpor (2012) argue that in many instances community members from disadvantaged backgrounds are often left out of critical water-related discussions due to the technical nature of the content, which hinders learning. Bundura's (1977) social learning theory emphasises that learning occurs once there is *attention*, *retention*, *reproduction* and *motivation*.

Kubwika (2013) emphasises that schools are the key role players in the intergenerational sustainability of water resource management; hence the need to involve as many of them as possible in citizen science development agenda. Tweddle, *et al*., (2012, p.4) emphasise three categories of citizen science projects that should be taken into consideration when designing citizen intervention strategies:

Contributory projects: designed entirely by the scientists and involve communities at a later stage.

Collaborative projects: Scientists take the lead in designing projects, but involve members of the community at different levels of the design process.

Co-created projects: Partnership in the creation of projects by the community members and the scientists.

It is clear from the points raised above that the scientists need to carefully analyse how they facilitate the presentation of citizen science in order to achieve social learning. Monitoring river health does not need to centre around government institutions only; communities have a role to play in the presence of the scientists and beyond.

2.12 Governance and the monitoring of water resources

Southern African countries have subscribed to the principles of Integrated Water Resource Management (IWRM) as a way of achieving sustainable development. As part of IWRM, citizen science has the potential to build a local pool of knowledgeable people needed for decentralised water management responsibilities that can be taken on by those people closest to the resource (Braid and Gorgens, 2010). Besides being at the core of South Africa's water policies, IWRM underpins most of the Pan African Water Vision, enshrined in the strategies of the African Minister's Council on Water (AMCOW), New Partnership for Africa's Development (NEPAD) and the African Union (AU) (IWM-IHP, 2008).

The DWS in South Africa adopted the Water for Growth and Development Policy in 2009 to align its water management to international water policies. Relating to the collection of data on surface water resources, South Africa has been noted as one of the countries in the southern region with a wealth of information on surface and groundwater, while other neighbouring countries have very limited monitoring programmes (UNEP, 2008, p.36).

The focus of this study is on uMngeni River in KZN which was continuously receiving poorly treated effluent discharges from the Howick Waste Water Treatment Plant, near Pietermaritzburg (Graham and Taylor, 2014). Community members residing in the nearby informal settlements, along the banks of the uMngeni River, were trained in sampling and testing techniques using simplified clarifier tubes, and in the keeping of records of data for water quality monitoring. The selected informal settlement residents used in this process were given incentives for their contribution. When the Howick Waste Water Treatment Plant realised that this was happening, they started treating the effluent to acceptable standards (Graham and Taylor, 2014). This led to the wastewater treatment plant adopting new ways of treating the effluent to acceptable standards (Taylor, *et al.,* 2012).

Various discussions have revealed that citizens' involvement can lead to improvements in government accountability in the restoration of the ecological integrity of degraded rivers. A typical example is provided by a canoeing group concerned with the deteriorating state of the uMngeni

River and who formed what is today known as the Duzi-uMngeni Conservation Trust (DUCT). Today, DUCT is listed as a section 21 company protecting the health of two rivers (Msunduzi and uMngeni) jointly making up 200 km of water ways (Van Wyk, *et al*., 2009). DUCT monitors all different kinds of pollution, including faecal pollution, industrial pollution, and unregulated sand mining operations, and also report on bilharzia and remove alien invasive vegetation (Van Wyk, *et al*., 2009).

2.13 Summary

In this chapter I presented the literature review on citizen science highlighting both local and international key issues. The reviewed literature highlights facts that citizen science can play a significant role in supporting government efforts to address water quality challenges. In the context of this study, communities can use simplified science tools such as miniSASS in addressing water quality problems in their catchments. Many benefits were presented as pointed out in the literature; benefits such as the empowerment of community members with knowledge to understand the basics of water quality and understanding the overall stream ecology. Amongst the key points raised in the literature was the water resource data submitted by non-scientists which does not, in most cases, get utilised due to the issues of inaccuracy, unreliability and lack of authenticity. Voluntary participation of citizens should give them a voice in the governance of their water resources. Citizen's involvement can lead to government's accountability. Lastly, the use of technology in addressing water quality challenges can bring about change in the manner in which the water resources are managed. Development of Google Earth–based monitoring of water resources allows data to be shared across national boundaries.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

In this chapter the researcher explains the research design and the methodology that was used to answer the research questions. The researcher also provides details of the process followed in data collection in line with the case study research design which was followed in this study. Amongst others, this chapter presents the significance of conducting the study in the KZN catchments of Msunduzi and uMngeni, and also provides some explanation of how the sampling process was carried out.

3.2 Research approach

In this study the researcher followed an exploratory and descriptive qualitative enquiry while pursuing multiple (3) cases involved in the implementation of miniSASS in KZN, in an effort to understand the social realities behind the phenomenon. There are two main approaches available to researchers, quantitative and qualitative approaches. Each research approach has its own strengths and weaknesses. Based on the research objective pursued by this study, a qualitative method was adopted because of its relevance to the research objectives and purpose of the study. The advantage of using a qualitative method for data collection specifically in this study is that qualitative studies are concerned with understanding meanings that people have constructed and how they "make sense of their world" (Merriam, 1998, p.6). Merriam (1998, p.27) defines a qualitative case study as an intensive, holistic description and analysis of a single instance, phenomenon, or social unit. In this study the researcher applied the qualitative research method because of its advantage in understanding cases involved in the monitoring of water resources, at least within the period from 1998 to 2013.

As opposed to a quantitative approach, qualitative methods are known for in-depth data collection as they create opportunities for gaining insights into social realities (Maree, 2011, p.50). Bless Higson-Smith and Kagee (2006) state that the application of a qualitative approach is required on topics where not enough description has been done before. In order to understand the social realities of the perceptions and experiences of the use of citizen science in monitoring and management of water resources, the qualitative approach allowed the researcher to understand the respondents' stories based on their involvement in the use of a citizen science tool, miniSASS, over a period of 15 years. The intention of the study was not just to gather numerical indicators of the experiences and perceptions of the use of citizen science tools, but to understand the reasons why citizen tools should further be considered for monitoring water resources (Henning, 2004).

3.3 Research design

Research design is defined by Terre Blanche and Durrheim (2002, p.29) as a strategic framework for actions serving as a bridge between the research questions and the execution of research. They further note that a research design should basically provide a plan for how the research is going to be executed (Terre Blanche and Durrheim, 2002, p.29). When deciding on an appropriate research design, researchers need to understand what the focus of the study is, the units of analysis and the time dimension of the problem being investigated (Bless, *et al*., 2006).

This study followed an exploratory and descriptive form of research using the case study design to understand the perceptions and experiences of the miniSASS users in Msunduzi and uMngeni catchments. Merriam (1998, p.8) defines a case study as a "bounded system and integrated system" selected because of its uniqueness, or based on it being highly successful. Indeed the chosen case studies are unique and considered as successful implementers of miniSASS in KZN. The advantage of following the case study design in this research was the need for the researcher to dig deeper into the cases and understand, from the miniSASS users' standpoint, details pertaining to the experiences and perceptions. The advantage of case study designs is that they cater for enquiries that are unique.

3.4 Data collection methods

In qualitative research there are three major sources of data collection, which are interviews, observations, and documents (Merriam, 2002, p.12). In this study the researcher collected data using two methods: firstly, document analysis of key documents intrinsic to each case and, secondly, semi-structured interviews, which allowed the researcher to draw as much information as possible on the issue of monitoring water resources in an unrestrictive manner based on each case (Bryman, 2008). As noted by Maree (2011) the aim of conducting interviews is to see the world through the eyes of the participant.

3.4.1 Primary data

Primary data refers to the first-hand information that is derived through interactions with research participants or the analysis of documents pertaining to the area being investigated (Bryman, 2008). Primary data undoubtedly has some advantage of allowing the researcher to get authentic and verified data. The researcher conducted semi-structured interviews as part of primary data collection.

3.4.1.1 Semi-structured interviews

Semi-structured interviews in qualitative research are commonly used to validate data that emerged from other sources (Maree, 2011). This type of enquiry involves a direct personal contact with the respondents (Bess, *et al*., 2006). Semi-structured interviews also need thorough preparation and time as they require a lot of probing and clarification of issues emanating from the enquiry (Maree, 2011, p.87).

The semi-structured interviews for this study were held in Durban and Pietermaritzburg over a period of two weeks. Due to time constraints, the researcher experienced some clashes in availability and arranged for two of the interviews to be concluded by email. While following a structured interview guide, the researcher applied probing techniques to dig deeper for meanings of points raised in each case. In order to capture a detailed encounter of each case, the researcher recorded the interviews using a digital recorder and captured some notes on a notepad as the discussion was progressing.

The semi-structured interviews in this study allowed the researcher to draw as much information as possible in an unrestricted manner from each participant (Bryman, 2008, p.471). The researcher occupied a central place in gathering data by steering the interviews towards the direction needed to dig deeper into insights based on each case (Maree, 2011).The researcher's interview guide allowed the researcher to probe each point necessary to inform the study, guided by techniques such as:

Detail probes: Clarity was sought using probes such as "who", ''what'', and "where".

Elaboration probes: These were used to get a bigger picture relating to a given response.

Clarification probes: The researcher paraphrased what was said by the respondent.

3.4.1.2 Documentary analysis

As part of data collection, document analysis is recommended by Rule and John (2011) as a good starting point in understanding the case when following a qualitative research approach. In this study, the researcher read the journal articles, published books and monitoring records relating to the case studies, as a point of departure. Of particular interest were the documents relating to the water quality incidents in Msunduzi and uMngeni sub-catchments. For each case it was necessary to read planning documents, business plans, newspaper articles, presentations and other communication material relating to river health initiatives. These documents formed a data bank for further elaboration on cases. Maree (2011, p.82) explained that qualitative studies dig deeper by evaluating existing documents related to the phenomenon under investigation. While explaining the advantage of using document analysis in case studies, Merriam (1998, p.126) pointed out that data derived from documents helps to ground the study in the context of the problem being investigated.

For each case, the researcher first analysed the documents relating to the history of the institutions involved in biomonitoring activities within KZN, as suggested by Ramenyi (2012, p.93). These included internal RHP documents, records of minutes, and data collection sheets generated for the river health initiatives of the uMngeni and Msunduzi catchments. Such documents were obtained from DUCT, Kloof Conservancy's Molweni School's River Health Programme, Palmiet River Watch and the Baynespruit Rehabilitation Project.

3.4.2 Secondary data

Secondary data refers to source material that emanates from other researcher's records such as books , journals and reports which were basically generated for other purposes but bear some linkage to the study at hand (Bless, *et al*., 2006). Other than books, secondary data is derived from published articles, graphs, and appendices of published articles (Church, 2001). Bryman (2012) states the advantage of considering secondary sources of data as saving cost and time. Researchers analysing secondary data sources have access to good quality data stored in archives accessed through websites (Bryman, 2012). Amongst others, Maree (2011) argues that the disadvantage of using secondary data is that the data itself can become too complex for the researcher to understand as they may not be familiar with the structure and contours of other researchers' data. In this study the researcher used document analysis, mainly through literature review (journal articles, books and reports), on information published about Msunduzi and uMngeni catchments.

3.5 Sampling

A sample is defined as a 'subset' of the population being studied which means that a sample must have properties that make it representative of the whole population (Bless, *et al*., 2006). Sampling follows different methods depending on the objective of the research. Appropriate in the context of this study was the purposive sample where sampling is done with a specific purpose in mind (Maree, 2011, p.178). In some cases the researcher followed a snowball sampling technique by getting suggestions of other possible respondents from the first group of respondents suggested by the gatekeeper. Maree (2011) confirms that snowball sampling is also known as 'chain referral sampling' as it leads to what is sometimes referred to as 'hidden populations'. A gatekeeper in this study refers to the GroundTruth employee who was managing the miniSASS database who assisted the researcher in identifying relevant respondents based on the miniSASS data uploaded on the Google Earth database.

The researcher managed to combine both purposive and snowball sampling techniques to recruit 15 participants, but only 10 were eventually available for interviews. With the help of the gatekeeper the researcher managed to recruit individuals that were experienced and had an impressive track record of using miniSASS in their catchments. The chosen participants were able to shed light on the enquiry, as noted by Rule and John (2011). Of particular concern was the need to get participants who have been actively involved in biomonitoring activities on a voluntary basis within the Msunduzi and uMngeni catchments for 15 years.

In order for the researcher to get a good sample the following criteria guided the recruitment process;

- Participants resident in KZN – Pietermaritzburg and Durban.
- Participants who currently work with or previously worked with water quality monitoring, for at least five years
- Participants who worked with communities in biomonitoring using miniSASS
- Participants who have done research on the citizen science projects related to water quality and data collection
- Participants who have worked in the design and implementation of the River Health Programme
- Participants that have facilitated miniSASS training sessions.
- Participants that have practically used miniSASS

As noted by Ramenyi (2012), researchers do not need to waste time with organisations or participants that do not meet the study requirements. Suitability profiles listed below indicate the target groups within KZN.

Department of Water and Sanitation: Two respondents from the national office, one from the Resource Quality Services (RQS) chief directorate and another who worked for the RHP and used SASS5 for the national water quality monitoring programme. Both respondents were SASS5 accredited.

Msunduzi Municipality*:* One respondent, a student who monitors the Baynespruit catchment in Pietermaritzburg working closely with eThekwini Water and Sanitation, Department of Environmental Affairs, DUCT, WESSA and GroundTruth.

Duzi uMngeni Conservation Trust (DUCT) and WESSA: Two respondents both had worked for DUCT and WESSA leading school environmental programmes. WESSA and DUCT have dedicated programmes for working with communities in monitoring the health of the Msunduzi and uMngeni Rivers. One respondent has actively been monitoring uMthunzima stream that runs past the Mpophomeni Township and the other had monitored Lions and Mpofana rivers.

Local researchers/ecologists and university students*:* One student was actively monitoring the Umgeni, Lion's and Mpofana rivers and also sampled the Mthunzima and Ndiza streams. Students from the University of KwaZulu-Natal are doing their Honours, Masters and PhD studies and use miniSASS as a research topic.

Molweni River Health Project*:* Three respondents were interviewed. One respondent was the leader of the project and one was a teacher from KwaBazothini High School in Molweni (located in the peri-urban area near Kloof) and a former teacher at Kloof High School. The project was initiated by Kloof Conservancy in 2012 and involves seven schools within Molweni catchment. They monitor the health of the Molweni Catchment at least twice a year, in winter and summer.

Palmiet River Watch: One respondent was interviewed. A group of about 250 residents in Westville are jointly monitoring the Palmiet Catchment which was heavily impacted by industrial pollution from the local dye-producing firms. Significant improvements have been realised through citizen science interventions.

3.6 Data analysis

Data analysis in qualitative research approaches is not a linear process, meaning that it is an iterative process, implying that data collection, analysis and reporting are intertwined (Maree, 2011, p.99). Data analysis allows the researcher to detect consistent patterns within the collected data (Bless, *et al.*, 2006, p.163). The aim of analysing data is to summarise what the researcher saw, heard and identified as common words, phrases, themes or patterns (Maree 2011, p.100). Bryman (2012) states that through data analysis the researcher aims to reduce the large corpus of information gathered in order to make sense of it. Additionally, depending on the research design, data collection can take one of the approaches under a list including hermeneutics, content analysis, conversation analysis, discourse analysis and narrative analysis (Maree, 2011, pp. 100-101).

In order to derive meanings out of the collected data, the researcher followed a qualitative content analysis approach. As defined by Bryman (2012, p.290), content analysis helps the researcher in allocating data in predetermined categories. Bryman (2012) further notes that qualitative content analysis places emphasis on the categories that emerge out of data. This approach made it possible for the researcher to understand the interpretation of data gathered from the interviewees and documents on the use of citizen science for monitoring rivers. Open coding of data was employed such that the researcher could break data down into parts that are compared using 'what' 'where', 'when' 'who' and 'how' (Henning, 2004). Maree (2011, p.101) refers to content analysis as an approach applicable in the analysis of books, brochures, written documents, transcripts, news reports and visual media. Once the emerging patterns, concepts and explanations were noted, data was then sorted and transcribed from all of the recordings and written notes (Maree, 2011). Lastly, the researcher checked for the common themes to inform the findings.

3.7 Validity and reliability

The researcher adhered to the criteria noted by Bryman (2012, p.390), who highlighted the following;

<u>Credibility</u> – The researcher has requested that the study be submitted to the 'Citizen Science' steering committee at the WRC.
<u>Dependability</u> – The study aimed to prove reliability such that if it were to be done at another time the results would still be the same.
<u>Conformability</u> – The researcher tried to maintain a high level of objectivity during the data gathering process.

Respondent validation – If the responses were unclear the researcher took the messages back to the respondents and verified the facts with organisations that provided interviews.
In order to achieve the reliability of data, the researcher did the following;
Grouped data into categories –developed different categories for grouping data.
Data analysis – referred to the interviews conducted by other researchers (Bryman, 2012, p. 390).

3.8. Limitations of the study

Data collection was constrained by limited financial resources as the researcher needed to travel from Gauteng to KZN for conducting interviews within Msunduzi and uMngeni Catchments. The interviews were done in Pietermaritzburg over the course of two weeks, from 19 to 23 January 2015, which imposed time constraints and led to some participants only being available for interviews at the same time and possible chances of getting more interviews were not achieved. Therefore some participants were requested to send their responses by email. Another issue of concern was that the researcher failed to secure interviews with the officials from the Department of Water and Sanitation within KZN, who could have added value to the findings of this study. The researcher thus relied more on participants suggested by the gatekeeper and through the snowball sampling technique, which unfortunately did not point her to the officials from the Department. According to the gatekeeper, the Department of Water and Sanitation was not actively using miniSASS and uploading data on the database and the selection of respondents for this study was based on active users of the miniSASS website.

3. 9 Ethical considerations

It is important that researchers adhere to ethical guidelines in carrying out studies. Amongst others, the issue of confidentiality is one ethical aspect that protects the participants contributing to the research results and findings (Maree, 2011). Of paramount importance is the protection of participant's identities which includes obtaining letters of consent, requesting permission to conduct interviews and destruction of audiotapes soon after data has been used (Maree, 2011, p.42).

Additionally, in research ethics it is very important to strike a balance between supporting freedom of scientific research and also protecting the welfare of participants (Bless, *et al.,* 2006, p.140). This research ensured that the rights of all the participants were protected throughout the data collection and analysis period (Yin, 2009). To ensure the protection of participants was adhered to, a consent form was signed prior to each interview (Maree, 2011). The letter specified that participants could discontinue their participation if they felt the need to do so at any point (Bless, *et al*., 2006).

3.9.1 Anonymity and information

Firstly, the researcher made arrangements prior to the interviews by sending a letter to each participant. The letter was signed by the Wits University Public and Development Management Unit and sent to each potential participant, requesting and securing dates for interviews. During interviews a consent form was therefore issued, read and signed by each participant prior to the commencement of interviews. The signing of the consent form ensured that privacy and confidentiality were maintained (Yin, 2009, p.73). In order to keep the participants anonymous, the researcher used pseudonyms to maintain confidentiality (Bryman, 2012). The participants were assured that all of their contributions were to be used for academic purposes only and would be archived by Wits University after transcription and the analysis of data was completed (Maree, 2011).

3.9. 2 Confidentiality

As indicated above, the confidentiality principle in research ethics relates to the protection of participant's identities by keeping records anonymous (Bryman, 2012). Confidentiality even includes the protection from harm that may occur in the process of data collection and presentation of findings (Bryman, 2012). In the case of this study the participants were approached well in advance and clarity was given on issues pertaining to their involvement in the study. Prior to the interviews the researcher explained the confidentiality principle so that informed consent was ensured as pointed out in Maree (2011).

3.10 Summary

This chapter has outlined the process that I followed in collecting data for answering the research questions. The chapter explained why I chose to use the case study research design and the qualitative approach for collecting data. The chapter highlighted the use of semi-structured interviews and documentary analysis as the primary data collection techniques. The criteria used in selecting the sample relevant for each case were given. The chapter also indicated how reliability and validity, anonymity and confidentiality of information provided by participants were ensured. The data analysis process applied in this study was also mentioned in this chapter. Lastly, the chapter also gave some indication of the constraints that prevailed during the data gathering process.

CHAPTER FOUR

DATA PRESENTATION

4.1 Introduction

In this chapter the researcher gives a detailed presentation of results derived from the citizen science case studies in uMngeni and Msunduzi catchments. The case studies presented in this chapter are Palmiet River Watch, Baynespruit Rehabilitation Project, and Molweni River Health School's Project. The findings of the research results presented in this chapter hinged on the main research question which was "How has miniSASS been perceived and experienced as a citizen science tool in uMngeni and Msunduzi catchments?"

The interviews were carried out in Durban, Pietermaritzburg and Pretoria over a period of two weeks. During interviews the researcher used probing questions to explore the perceptions and experiences of the use of citizen science in monitoring water resources of Msunduzi and uMngeni catchments.

Prior to the interviews the researcher had worked with a gatekeeper to make an appropriate selection of potential respondents in the two catchments. Out of the miniSASS database 15 active miniSASS respondents were identified and only 10 could be secured for interviews. The main research question that guided this study was; "How has miniSASS been perceived and experienced as a citizen science tool in uMngeni and Msunduzi catchments?" The study further sought clarity by posing complementary research questions as listed below:

- What has happened over the past 15 years to improve the conditions of river health in KwaZulu-Natal within uMngeni and Msunduzi catchments?
- How has miniSASS assisted in improving the governance and management of water resources in KwaZulu-Natal?

- How has the integration of technology-based monitoring tools for water resources enhanced citizen participation in river health monitoring and management in KwaZulu-Natal?

While using the interview guide each question was accompanied by a number of sub-questions that were used to dig deeper into the case studies to address the experiences and perceptions on the use of miniSASS in water quality monitoring. Table 3 below indicates the profile of interviewed participants and their monitoring sites. All the participants listed below had been monitoring and uploading water quality data on the miniSASS database for 3 to 15 years.

4.1.1 Profile of interviewed citizen science activists

Table 2: Demographic profile of respondents

Respondent Number	Focus area	Number of years of miniSASS experience	Monitoring site
A	Kloof and Molweni	3	Molweni Catchment
B	Lower Mpushini	15	Mpofana and Lions river
C	Westville	3	Palmiet Catchment
D	Mpophomeni and Sobantu Townships	15	Umthunzima stream
E	Msunduzi Municipality	3	Baynespruit Catchment
F	Kloof	3	Molweni Catchment
G	Lower Molweni	3	Molweni Catchment
H	Msunduzi Municipality	15	Upper Umgeni catchment, Umgeni, Lion's and Mpofana rivers Mthunzima and Ndiza streams
I	National monitoring programme	15	All catchments in South Africa
J	National monitoring programme (RHP)	15	All catchments in South Africa

Source: Own, 2015

4. 2 THE CASE OF PALMIET RIVER WATCH

4.2.1 Background

The Palmiet is one of the uMngeni tributaries, rising on Fields Hill and joined by a branch which rises below Wybank municipal dump site. The Palmiet flows through Manors, parts of Padfieldpark, New Germany residential and industrial areas, Mountain Ridge, Pinetown industrial area, Cowies Hill, Westville, Palmiet Nature Reserve, Westville, Suzor's Bend, Clair Hills and Palmiet, and joins the uMngeni River near Papwa Sewgolum golf course and the N2/Inanda bypass. The Palmiet River catchment comprises some 25 km of stream length and includes residential, commercial, industrial, informal housing and natural areas (two nature reserves). The Palmiet empties into the uMngeni River estuary.

The Palmiet River Watch was formed after a door-to-door campaign led by one resident that eventually recruited all of the households along the banks of the Palmiet to take part in the monitoring of water quality. Although the Palmiet River Watch does not meet regularly, the forum is kept intact through the 'WhatsApp' cell phone and email chat-group called 'Let's talk rubbish' and led by its founder. According to the respondent this chat-group actively reports incidents occurring in various parts of the catchment, which ultimately get reported to eThekwini Municipality to take action.

The Palmiet River Watch strives to monitor and report all environmentally undesirable activities throughout the catchment for urgent attention by the municipal authorities, such as sewage pollution, trade effluent pollution, and freshwater pipe-bursts, stormwater damage, dumping in streams and rivers, defective septic tanks and other water-related problems.

Figure 7: Palmiet River affected by industrial waste

Source: Highway Mail, 2015

4.2.2 Palmiet River Watch – sources of data

Although the Palmiet River Watch has 250 active monitors of the catchment, only one respondent was interviewed. The interview was held at the offices of the Palmiet Conservancy Nature Reserve in Westville. At the end of the interview the researcher was taken to the stream to see how clean the water has become after the Palmiet River Watch's intervention. The stream was highly polluted as indicated in Figure 7 above. To get more supporting data, the respondent provided articles that were published in the local newspapers. The *Highway Mail* published an article on 1 October 2013 entitled "Watch keeps an eye on Palmiet River". Another article published on 19 December 2014 was entitled "Palmiet Pollution takes a toll on wildlife". These documents validated the information shared by the respondent during the interviews and the contents have been cited in the text below.

4.2.3 Pollution incidents in the Palmiet

For a number of years community members residing along the banks of the Palmiet River in Westville had expressed concerns over the river that was abused and used as a drain (DUCT, 2013). Due to the industries located upstream, it was common for residents to frequently see the foam on the Palmiet River. The local newspaper, *Highway Mail*, also reported incidences of dirty blue, then green, grey, black and brown, foul-smelling, soapy river water accompanied by cleaning agents. In many instances, residents complained about dead crabs, frogs, fish and bewildered birds floating in the river (Highway Mail, 2013).

According to the respondent the water quality of the Palmiet was continually affected by a series of sewer blockages, sewer pump station failures and raw industrial effluent pouring into the Palmiet via the sewer and stormwater network (Highway Mail, 19 December 2014). Residents observed different forms of pollution for years. There were reports of foam standing a meter tall at times, which blew into residents' yards. Detergents were being discharged into the stormwater system regularly on Fridays and Sundays, the Highway Mail reported. The Palmiet River Watch, formed in May 2013, managed to remodel their activities based on those of the former Palmiet Nature Reserve Conservancy which had been in existence in the catchment for a period of 15 years with no tangible results.

> *Prior to the formation of the Palmiet River Watch… pollution events often went undetected, contaminating the river water continually; and complaints often went unresolved. River Watch reporting revealed that severe pollution events take place regularly, and continually destroy riverine habitats and annihilate the creatures that belong in the catchment* (Respondent C, 22 January 2015).

"The catchment currently shows significant improvements, thanks to the residents and businesses in the area, who persistently submit meaningful water condition reports enabling the authorities to trace pollution to its source, identify polluters and take corrective action, often within a few hours", explained the respondent.

Although water pollution has been reduced, it remains far from being 'acceptable', stated the respondent. By January 2015, the river water was reported as often “clear”, “sparkling”, and sometimes even described as “like a berg stream”.

4.2.4 miniSASS data and elimination of polluters

Although there had been community activism for the past 15 years in monitoring water quality within the Palmiet River, there were no visible improvements until the newly formed group remodelled the monitoring initiatives. As part of their river health monitoring initiatives, miniSASS was considered after Respondent C had consulted with the miniSASS developers in September 2014 and was trained on how to implement it in the Palmiet catchment. Ever since monitoring started, it has been giving interesting results in different parts of the river, the respondent stated. According to Respondent C miniSASS has helped in tracing upstream conditions and adjacent land-use activities polluting the river (industrial, commercial, residential, open space, and informal housing), and in conjunction with rainfall measurements and records of pollution events.

Respondent C indicated that the intention of the Palmiet River Watch is to use miniSASS data, along with other tests such as for *E. coli*, to identify and eliminate sources of pollution and deal with polluters. However, there is a whole range of additional activities that are done that are not directly related to the water quality data but also use miniSASS data.

> *When it comes to miniSASS I just saw it as one of the range of tools that I needed to use to reach our river health objectives. The data collection exercise itself has gone a long way toward familiarising myself with the river, incoming streams and possible sources of pollution. For example a serious infestation of rat-tailed maggots was found at one miniSASS site which will be followed up in the first quarter of 2015* (Respondent C, 22 January 2015).

Through Palmiet River Watch’s intervention a dedicated municipal team has started undertaking door-to-door inspections which have resulted in a number of warnings, and some prosecutions, pertaining to water pollution (Smit, 2014). eThekwini Municipality has achieved a remarkable reduction in and elimination of fresh-water supply-pipe bursts that were tearing the riverine habitats apart (Highway Mail, December 2014).

> *When the miniSASS assessment was undertaken in November 2013 the river looked and smelled terrible and was almost devoid of any form of life. Only one minuscule worm, a tiny crab and one snail was found. The most recent miniSASS assessment revealed that there is currently an abundance of insects and other organisms in the stream. It will take time for the chemical pollutants to leach out of the subterranean soils* (Respondent C, 22 January, 2015).

Other water quality monitoring techniques are used in the Palmiet catchment to complement the miniSASS data. For example, the respondent cited the *E. coli* count monitoring as useful in locating the sources of sewage pollution to validate miniSASS findings.

Water quality monitoring within the Palmiet Catchment follows a structured reporting process. A WhatsApp chat group was formed after the founder of the Palmiet River Watch had made door-to-door visits to all of the residents bordering the Palmiet River. Ever since it was formed, the chat group has been very active in driving the water quality monitoring process. Respondent C elaborated further on the formation of the chat group:

> *When somebody sees something, they put it on a WhatsApp group and then people upstream then respond and say no it's clear here or whatever … and then the people who aren't on WhatsApp we communicate to them with sms's or phone calls. We also ensure that we've also got a set of information that we need; which is the colour, clarity, the odour, if the volume or the water has changed significantly. I then get a registration number or reference number for that complaint*

and then I follow up and discover within an hour, and resolve a problem within a day (Respondent C, 22 January, 2015).

The Palmiet River Watch relies on individuals along the length of the river and on side-streams to do regular monitoring and reporting of abnormal water conditions. Group members take note of undesirable activities within their catchment and report them. The ongoing visual monitoring and reporting has contributed significantly in locating and reducing industrial and commercial pollution upstream. It helped the Department of Water and Sanitation to determine what the pollutants are and where they originated from, which has enabled the authorities to narrow down the options in the search for polluters.

According to the Palmiet respondent, 'pollution incidents' are reported by residents indicating its location and also providing a visual description. After reporting each incident a reference number is obtained from the eThekwini Municipality and the results monitored. Unsatisfactory results have been shared with officials so that they can take corrective measures. Each report gets a reference number for each case reported which is given to the group as a record. Each reported case is linked to the reporter's street address and contact number (Highway Mail, 2013).

4.2.5. Discussion

Within three years of its establishment, the Palmiet River Watch has already made a notable change by tackling industrial pollution troubling the catchment. This meaningful change started as one man's effort that succeeded in bringing in other residents to act as watchdogs for a strip of river and encourage continuous reporting of every undesirable event. The catchment displays a virtual forum, uniquely bounded by modern mediums of communication technology and strengthening each and every case that gets reported to eThekwini Municipality.

The case of Palmiet River Watch interestingly shows how community reporting contributes significantly in locating and reducing industrial and commercial pollution. The use of the miniSASS citizen science tool continually assists the Palmiet River Watch to generate data that eventually leads to the direct tracing of polluters of the local stream.

4. 3. THE CASE OF MOLWENI RIVER HEALTH SCHOOLS' PROJECT

4.3. 1 Background

The Molweni River Health School's Project was conceptualised by the Kloof Conservancy with the help of GroundTruth and WESSA in 2012. Kloof is located 30 km west of Durban CBD. The conservancy has been actively running several community-based environmental projects; however, the school's river health initiative exclusively focusses on educating the schools about water quality assessment using miniSASS as one of their testing tools (www.kloofconservancy.org.za).

4.3.2 Sources of data

Semi-structured interviews were held with one respondent from the Kloof Conservancy leading the Molweni River Health School's Project. Respondent A referred the researcher to the Kloof Conservancy website www.kloofconservancy.org.za) for more documents on the project. The respondent further provided data related to the monitoring sites in Molweni catchment. Additionally, the article published on the mayoral award was suggested by Respondent A for further reading on the project's achievements (see 4.3.6).

4.3.3 Molweni River Health School's Project

According to Respondent A, the initiative of working with the schools within Molweni Catchment was practically implemented in 2013, with seven schools conducting water sampling at different points in the catchment. The project aims to monitor the health of Molweni River and its tributaries and report data to eThekwini Municipality. At the time of writing this report, the participating schools were Thomas Moore College, and Kloof, Hillcrest, Wyebank, Kwabazothini, KwaDinabakubo and Tholulwazi High Schools. This initiative combines schools from both urban and peri-urban areas of Kloof and Molweni.

4.3.4 The Water quality monitoring process

The Molweni River Health School's Project Respondent A stated that the Kloof Conservancy firstly makes arrangements with the Life Science educators and visits all the schools prior to the water sampling day to give talks around water generally, and to explain the need to monitor water resources. The talk is normally presented by a water resources expert to the whole school, after which five learners from Grades 10 and 11 are selected to participate in the practical sampling activity. Respondent A emphasized that sampling is done twice a year in February when the flow is high and in August when the flow is low.

Amongst others, the objectives of the project are (www.kloofconservancy.org.za):

- To provide an educational opportunity for high schools in the Molweni Catchment to learn about water resources and the importance of water in an innovative and fun way
- To raise the awareness of communities in the Molweni Catchment about the importance of water to the whole community while spreading information about the project and its resultant actions
- For communities to understand environmental issues with no boundaries
- To provide communities with an opportunity to identify and report issues affecting their catchment to the relevant authorities and follow up on remediation

The Molweni River Health programme has been supported by partner organisations such as GCS Water and Environmental Consultants; and Royal HaskoningDSV; as well as eThekwini Metro Water and Sanitation; Durban Solid Waste; eThekwini Natural Resources Department; eThekwini Coastal, Stormwater and Catchment Management; Umgeni Water; KZN Department of Economic Development, Tourism and Environmental Affairs; Krantzkloof Honorary Officers; and Ezemvelo KZN Wildlife. The project is also sponsored by Waterfall SPAR which provides snack packs for the learners on the day the event is held.

4.3.5 Using miniSASS for monitoring water quality

Understanding the sampling procedure is important for generating reliable and authentic data for each sampling site. The Kloof Conservancy relies on the presence of miniSASS experts during the day of sampling for generating data that can be trusted, echoed the Kloof Conservancy respondent. Of paramount importance when sampling using miniSASS is the choice of a suitable sampling point. The best sampling point is characterised by the availability of stones in fast-flowing water and there must also be vegetation growing on the sides of the river (Graham, *et al.,* 2004, p.33). Sampling points used by Molweni River Health School's project are listed in Table 2 below.

Table 3: Sampling points in Molweni Catchment

Monitoring station number	Name of monitoring station	Allocated school
1	Springside Nature Reserve – Molweni Source	Hillcrest High School
2	Interpretive Centre – Molweni River	Thomas Moore High School
3	Memorial Park – Ronald Kloof Stream	Kloof High School
4	Kloof Uve Stream	Wyebank Secondary School
5	Nkutu Picnic Site – Nkutu River	Kwabazothini High School
6	Molweni Valley – Molweni River	Tholulwazi Secondary School
7	uMngeni Confluence – Molweni River	KwaDinabakubo High School

Source: www.kloofconservancy.org.za

Respondent A also reported that after miniSASS sampling has been done the learners are instructed to collect additional samples which they give to eThekwini Metro Water for full chemical analysis. Normally, the schools' samples give an *E. coli* count of 1 000 to 5 000 and eThekwini Metro Water is less worried about such results because anything below 10 000 is not a serious problem.

> *When doing the miniSASS assessment the results come out generally poor and … that is quite disturbing because we have a clean river system. That is a bit of a puzzle. The catchment is actually a clean catchment. There are no industries here. There is nothing bad. We've gotten to the point where we have to reassess now. We also do the chemical analysis (Respondent A, 19 January 2015).*

The Kloof Conservancy works closely with a Durban-based private company, GCS Water and Environmental Consultants, who work with the teams on the day of sampling, consolidate the results and present the overall report on Molweni Catchment. Data is then supplied to the central miniSASS database (www.minisass.org).

A few cases of pollution from a local laundry business were spotted and also one household that washed paint brushes directly into the river; these cases were dealt with immediately. The respondent reported that poor miniSASS results are an indication of stormwater drainage problems during summer. The second suspicion is that the whole Kloof area does not have a proper sanitation system. Kloof relies on soakaway pits. The respondent confirmed that this is a mere suspicion based on the fact that it has been noted that soakaway pits are badly maintained in Kloof.

> *…. when we report this to eThekwini Metro, they still say it is not that bad (Respondent A, 19 January 2015).*

According to Respondent A the community members are alerted about the results via the press. If there are serious concerns affecting the sampled rivers, the matter is then reported to the eThekwini Water and Sanitation division to take necessary action.

> *The educational value is always good. First of all, the project has an educational element. No matter what the quality of the water is … the educational value is always a good one…* (Respondent A, 19 January 2015)

4.3.6 The Mayoral Award for Excellence

After two years of monitoring the Molweni Catchment, the eThekwini Mayor, Councillor James Nxumalo, recognised the Molweni River Health School's Project for its excellence in the Biodiversity Category, at a ceremony held at the Durban International Convention Centre on 12 December 2014. Elaborating on the award the respondent pointed out that:

> *The award is a credit to the entire team that has been (and continues) working on this project for over two years. The project is a joint venture between Kloof Conservancy (a number of members have contributed their time (over two years the project has been running) involving all the supporting organisations (Respondent A, 19 January 2015).*

4.3.7 Molweni River Community Park Project

In order to save the Molweni Catchment from further degradation, the Kloof Conservancy's dream was to establish what they call 'River Custodians' going forward. Reports have already been made about current illegal dumping of litter and people washing clothes in the river, the respondent explained. This gave birth to the idea of creating the Upper Molweni Community Park which will be a recreational facility and also save the river from abuse. The Molweni River Community Park project was launched in Upper Molweni Hall on 8 December 2014 and, once completed, will hopefully benefit the community and add value to the beauty of their river.

4.3. 8 Discussion

The Molweni River Health School's Project started in 2013 and has shown impressive progress and commitment towards a pollution-free catchment. In the Molweni catchment specifically, monitoring activities are centred on the local school which makes the initiative much more sustainable. Since the establishment of the Molweni schools monitoring initiative, miniSASS is used as a key data analysis tool after which the results are then verified through chemical analysis. However, the biggest concern bothering the monitoring groups is the need to locate the causes of water contaminants since they believe the catchment is pollution-free. For fixing any problems in the catchment, the Kloof Conservancy trusted its 'right connections' within the municipality.

4.4. THE CASE OF BAYNESPRUIT CATCHMENT REHABILITATION PROJECT

4.4. 1 Background

The Baynespruit is a small tributary of the Msunduzi River originating from the Northdale and Raisthorpe areas and passing through Willowton industrial area, past the informal settlements and the Eastwood and Sobantu Townships before reaching its confluence with the Msunduzi (Dent, 2011). The stream length is 9 km. The water from the Baynespruit flows into the Msunduzi River and joins the uMngeni to form part of the Inanda Dam, which supplies water to major parts of eThekwini Municipality (Baynespruit Rehabilitation Project, SANBI, no date). The Baynespruit catchment is affected by effluent discharges from the local industries that produce wax and dye and in most cases waste from the residential areas (see Figure 8 below), affecting the water quality (Dent, 2010). Poor water quality remains a problem due to the poor sanitation infrastructure, stormwater drainage pipes that are not aligned, and wastewater discharges through sewer networks. The informal settlements built closer to the river are also posing a serious challenge. Since 1990 the *E. coli* count has been above 1 million per 100 ml on most of the occasions that testing was done, exceeding the Department of Water and Sanitation's safe level for swimming of 130 counts (Dent, 2010).

Figure 8: Pollution in Baynespruit

Source: Witness

4.4. 2 Sources of data

The researcher managed to secure one interview for the Baynespruit catchment. Respondent E was suggested by the gatekeeper based on the miniSASS monitoring track record in this catchment. Secondary data was drawn from the published journal articles that presented Baynespruit as a case study with regards to water pollution challenges and stakeholder participation (Dent, 2010). Another report published by SRK Consulting (SRK Consulting, 2009) assisted the researcher in gathering more background information about the catchment. Other supporting documents were the newspaper articles published by *The Witness* on 20 November 2014 entitled "Drive to save the river, concern over future supplies leads to Baynespruit clean-up". Another article published in the same newspaper on the same date was entitled "Bringing a river back to life, Project to clean up the Baynespruit sees some success as the northern suburbs stream shows signs of coming back to life".

4.4.3 Rehabilitation activities in Baynespruit

In order to solve the water quality challenges, Msunduzi Municipality initiated a Baynespruit Rehabilitation Project in 2013. The project is a response to the call made by eThekwini Municipality to Msunduzi Municipality about the declining water quality that was affecting the uMngeni River (The Witness, 20 November 2014). Other than the economic and environmental benefits, rehabilitating the Baynespruit was aimed to bring confidence in the continuation of the popular annual Duzi Canoe Marathon for which the river is used (SANBI, no date). Rehabilitation forms part of the eThekwini Municipality and uMngeni Ecological Infrastructure Partnership (UEIP) (The Witness, 20 November 2014).

4.4.4 Monitoring water quality in Baynespruit catchment

Efforts to rehabilitate the Baynespruit have been made possible through the partnership Msunduzi Municipality established with DUCT, WESSA, GroundTruth, and Environmental Engineers (Ramburran E, personal communication 2014). As part of the Baynespruit Rehabilitation initiative, the Msunduzi Municipality has since been conducting numerous miniSASS tests along the Baynespruit River with students from the UKZN who are doing assessments for study purposes. The miniSASS collaboration with UKZN students has further been extended to the neighbouring schools and a local church. miniSASS results have started assisting Msunduzi Municipality in addressing some of the identified problems affecting the stream. Respondent E emphatically pointed out during the interview that his work was a feeder into a much larger project, the Baynespruit Rehabilitation project, which is being run by the Environmental Department of the Msunduzi Municipality. The information acquired using miniSASS and IHI (Invertebrate Habitat Integrity) data was submitted to them and helped them in locating some of the badly affected parts of the river and to ‘red flag’ some of the problems that need to be addressed. Reference has been made to the articles in the discussion below.

The IHI helps to identify problems such as erosion, dumping, alien invasive plants and modifications to the flow of the river. The findings from these assessments have contributed to the rehabilitation process of the Baynespruit. Respondent E pointed out in his response that:

> *The municipality has already started addressing these issues by upgrading the previously leaking sewer lines and clearing invasive plants and planting indigenous plants. Along the Baynespruit, some of the main sources of pollution were industry and domestic waste which was being disposed of by surrounding communities* (Respondent E, 28 January 2015).

Figure: 9 miniSASS sampling in Baynespruit

Source: Msunduzi Municipality

According to an article published in *The Witness* (November 20, 2014), the local church under the leadership of Pastor Anthony Naidoo, the Jesus Miracle Revival Church, acquired land along the Baynespruit which had been used as a dump site. When they started clearing the site, the Msunduzi Municipal worker from the Environmental Management Unit, Msunduzi Municipality, approached the church and introduced the river health tools for taking care of the spruit. The congregation became interested in joining the rehabilitation project. Through various clean-up sessions, the church now enjoys a free-flowing stream. In The Witness (November 20, 2014) article, the pastor echoed:

> *Environmental Department of Msunduzi Municipality saw our work, and approached us, and we got involved in the project, first in getting training in the miniSASS and then understanding monitoring the water quality* (Respondent E, 28 January 2015).

In most cases, garbage from the households is dumped in the floodplain or directly into the river. Already, the polluted water is affecting small-scale farmers in Sobantu, whose crops are dying due to poor quality of irrigation water (The Witness, November 20, 2014). The formation of partnerships between the municipality and the local communities is of paramount importance in solving the problems of the Baynespruit. Dent (2010) pointed out that partnerships and networks are needed to address economic, developmental and socio-cultural barriers to pollution problems of the Baynespruit. In his study Dent (2010) also pointed out that the biggest challenge is for both communities and the industry to understand the consequences of polluting.

4.4.5 Predicting the future of the Baynespruit

While responding to the question on the future of Baynespruit, Respondent E commented that the Baynespruit and ultimately the Msunduzi catchment will improve in quality, not only due to increased awareness and education but also because of the possible monetary losses in the tourism sector, e.g., loss of the Duzi Canoe Marathon and sponsors due to poor water quality. Although the changes will be slow, it will take a combined effort from both the authorities and everyone who is affected by it.

4.4.5 Discussion

The Baynespruit case study indicates a catchment that suffers from incidents of pollution from the residential areas and the surrounding industries. However, Msunduzi municipality has started addressing the problem by embarking on the rehabilitation project which is accompanied by budget allocations. Part of the rehabilitation activities is the partnership with the University of KwaZulu-Natal students to use miniSASS, Mathuba Schools and Citizens River Health Program and IHI to monitor the health of the Baynespruit. The Mathuba Program is another innovative community-based river health program that was developed by Dr Mark Dent, a senior lecturer at the University of KwaZulu-Natal. Mathuba Schools and Citizens River Health Program allows pupils to use cell phone technology to upload images and discuss issues affecting their water resources. The Mathuba Program inculcates to the users systematic thinking and the creation of mental maps (Hurry and Reinhardt, 2015). Partnership with the schools and the local church is a move towards involving more community-based catchment monitoring groups in Baynespruit.

4.4.7 Summary

In this chapter I presented the miniSASS user's experiences and perceptions based on the narration provided during interviews. For each case to give its full account, I had to follow the themes that emerged and guided the interview. Interestingly, each case emerged uniquely characterised by different water quality challenges and opportunities to engage citizens

CHAPTER FIVE

DATA ANALYSIS

5.1 Introduction

This chapter presents the analysis of findings in relation to case studies presented in Chapter Four. The main research question guiding the analysis of the research findings was “How has miniSASS been perceived and experienced as a citizen science tool in uMngeni and Msunduzi catchments?” The data gathered from the three case studies provided additional information for answering the main research question. Data analysis followed the qualitative content analysis as it captures the real world, seeing events through the eyes of the participants (Henning, *et al*., 2004). Data analysis was made possible through the development of codes and categories (Bryman, 2012).

5.2 Discussion of results

In this section the findings from the interviews and analysis of documents in relation to the main research question were analysed and grouped under the identified themes and also as responses to the three questions raised in this study.

5.2.1 Community empowerment

The educational value that miniSASS presents gives its users an opportunity for growth in science knowledge and, more specifically, knowledge on water and the environment. During the interviews Respondent A indicated that even though the quality of the water in their catchment was not so good, the educational value miniSASS offers to the 70 children that Molweni project involves is of great importance. With a scientist giving water talk prior to the practical miniSASS session in Molweni, the educational value of monitoring water is even more empowering. Respondent D (interview, 22 January, 2015) commented that monitoring river health has empowered young people who have 'come into their own boots' and said 'I am taking charge'. An example of a learner from Mpophomeni Township was cited as a success case as she has taken charge of building her own networks with local government authorities responsible for water in her area. Evidence of growth was also observed in learners participating in monitoring activities as they were said to bring in technical water concepts in classes revealing an understanding of water pollution as they present themselves in school subjects.

5.2.1.1 River custodianship

Water quality monitoring is further supported by the establishment of a cadre of river custodians called 'river watchdogs', as it was stated on numerous occasions during the interviews. A river 'watchdog' in the context of this study refers to a group of well-trained and motivated community members who are overseeing a particular stretch of the river (DUCT, 2013). Therefore, river walks and river clean-up campaigns are planned to attract communities to buy into the idea of river custodianship (DUCT, 2013). This view of forming river custodians was also expressed by Respondent A from the Molweni catchment as a plan to keep the catchment pollution-free. The Lower Mpushini Conservancy has, on the other hand, already started some of the activities to build custodians for the degraded Mpushini River which was reported to be bone-dry due to dam construction.

5.2.1.2 River clean-up days

Other than the use of practical science tools such as miniSASS, there is mobilisation of voluntary participation of citizens in cleaning up catchments under the banner of DUCT and WESSA. River clean-up days in Msunduzi and uMngeni have attracted canoeists, local schools and government departments (DUCT, 2013). One of the popular events in Msunduzi and uMngeni catchments is the International Coastal Clean-

Up Day held every year in September with volunteers cleaning up litter from local beaches and estuaries (DUCT, 2013).

Additionally, through voluntary participation DUCT has formed what is today known as ‘‘River Care Teams” who are trained to take care of a particular stretch of a river about 10 km long (Water Wheel, March, April p.15). Activities include the removal of alien invasive species, weed control, collection of trash, and act as overseers of illegal dumping of waste (DUCT, 2013). Respondent B indicated her involvement in this campaign and explained how miniSASS was incorporated into the river walks involving schools.

5.2.2 Raising awareness about pollution

According to Hilchey (2011) the miniSASS was perceived by all of the respondents as a tool for raising the ‘red flag’. Practically, this means drawing the attention of authorities to a problem that would otherwise have gone undetected for prolonged periods. Although most of the miniSASS users in Msunduzi and uMngeni Catchments testified to the use of additional water monitoring tools such as the IHI, Mathuba and chemical analysis, they all share the same understanding that miniSASS helps them determine ‘what’s going on’ in the catchment. All the respondents mentioned ‘a tool for awareness’ in their discussion. Through citizen science interventions spillages and pipe bursts have been spotted and addressed on a number of occasions in these two catchments.

In the Baynespruit, for example, the adoption of a citizen science approach helps to highlight underlying causes of problems that the authorities may not be fully aware of. For example, the Enviro Champs of Mpophomeni have helped to highlight that inadequate infrastructure is to blame for the sewage that flows from the township into Midmar Dam. This is because the pipelines in the township are too small and therefore fail to cater for a growing community. According to Respondent E the Msunduzi municipality has already started addressing upgrading of previously leaking sewer lines and clearing invasive plants and planting indigenous trees. Along the Baynespruit, some of the main sources of pollution were industry and domestic waste which was being disposed of by surrounding communities, which is now beginning to decrease.

5.2. 2.1 Identifying root causes of pollution

While explaining the intervention made by citizen science initiatives, the potential for combining miniSASS with the Mathuba program was noted as a great advantage. The Mathuba was defined by Respondents B and D as another citizen science tool that assists users to understand the underlying causes of pollution in a catchment. While miniSASS generates water quality data, the Mathuba program doesn't capture hard data, but captures the socio-economic issues behind data. According to Respondent D, Mathuba program actually uses the iceberg conversation tool to dig deeper and looks at the driving forces behind each problem. Respondent E was familiar with both miniSASS and the IHI to identify problems such as erosion, dumping, alien invasives and modifications to the flow of the Baynespruit, and also pointed out how the intervention has led to the municipality addressing problems that had persisted for a long time.

Respondent D confirmed that Mathuba program assists users in looking at problems in a systematic way to find the root causes, because very often people tend to just look at it as events-orientated. Mathuba uses an iceberg model of questioning and then engages users, having looked at what the problem is, to unpack the different layers of the causes, and then miniSASS plays a role of generating water quality data.

5.2.3 Governance of water resources

The study conducted by Munnik , Goldman, Jooste, Kola, Loate, Palmer and Fatima-Rawat (2013) indicated that most of the municipalities studied in South Africa performed poorly due to poor governance of their water resources. Good governance of water resources put people at the centre of water management and allow them to have a say in the manner they should be served. As water is increasingly becoming a scarce commodity, good governance structures put people first and so does citizen science. Citizen science allows people to take charge of their water resources and allows them a choice to live in a healthy or sick catchment (Palmer, *et al*., 2002). As noted by Hilchey (2011) transferring decision making authority to the local people about their resources leads to sustainable governance. Citizen science allows people to be decision-makers about their catchments.

As indicated earlier, miniSASS data has assisted the residents in Msunduzi and uMngeni Catchments to pinpoint the root causes of water quality problems that they identified. However, during the interviews none of the respondents indicated to have participated in the governance structures of their municipalities. They were happy with the connections (networks) they have within the municipal operational structures related to their work. Respondent B for example commented;

> *We have catchment management forums. I don't attend the meetings. But we have the chairman…. so I know what's happening. Through DUCT I am copied in. I know the quality of the water through uMngeni Water test results so every week I know the quality is of all the different river systems around through DUCT and through my connections with DUCT (*Respondent B, 20 January, 2015).

There has not been any significant government involvement in citizen science activities, except for a few cases where the NGOs (WESSA and

DUCT) are taking a leading role. This contradicts the view cited by Hinchey (2011, p.276) that the role of community based monitoring is to allow the government to ask for information from the public and make decisions involving local people.

While the Kloof area was considered by Respondents D and F as a pollution-free catchment, the use of miniSASS and the chemical water testing have on a number of occasions pointed to poor results which residents fail to understand. There was only one instance where the Kloof catchment was rated as 'fair', explained the respondent. For example, the residents blamed the old stormwater drainage system and poor sanitation infrastructure in the Kloof area for water quality results they get from miniSASS sampling. Contamination of water resources was linked to soakaway pits in the Kloof area. The whole of Kloof area relies on soakaway toilet pits. Respondent A suspected that this could be the cause but indicated that they really could not prove it. Soakaway pits are badly maintained, he noted. However, when the problem is reported to Durban Metro, they still say it is not that bad for them to worry because the *E. coli* count is not so high.

Regarding the miniSASS data and its reliability as a citizen science tool, different and interesting views were expressed by the respondents. Firstly, most of the responses pointed to the reliability based on the scientist presiding over the testing of water samples. According to Respondents B and D this was determined by the way the scientist draws the water sample, the choice of the sampling site and, in some cases, the equipment that was used for sampling. One respondent even pointed to the confidence of sampling as a contributing factor in getting reliable scores. miniSASS users need to be fully cognisant of the river status even before attempting to sample.

Contrasting views were expressed by Respondent I and J even though they were working for the same organisation. The contrast was about the issue of water quality data reliability. Respondent I was of the view that it is possible that people doing the miniSASS are not trained properly and there is a possibility that they make mistakes and such data cannot be used for planning processes. On the other hand Respondent J was concerned about the need to empower people such that they understand why they should be involved in monitoring and that using citizen science does not necessarily replace the government monitoring programmes.

According to Respondent B if the river system is very badly modified, like the Lower Mpushini which is now carrying extra water from the transfer scheme, then what they found was that if there is quite a high level of water flow and a high level of siltation then you are not going to get the characteristic such as 'good', 'moderate', or 'poor' conditions in the same way as for a 'normal water body': "If the system is modified and there has been water added to it , you are not likely to get good results." An example of the Mpushini River was given as it has been dammed up and alien vegetation has encroached, which Respondent B referred to as a collapsed river system that is not likely to give proper miniSASS results.

5.2.4 The use of technology in monitoring river health

Nowadays, citizen science is characterised by the integration of web-based easily accessible software that allows the public to gather and share data on mobile devices (Silvertown, 2009). Although the use of software has advantages, there are notable challenges such as keeping up with changing technologies (Silvertown, 2009). Dickens, *et al*., (2012) emphasise the educational value in the use of technologies to promote science.

Although the integration of technology-based monitoring was known to most of the respondents, it has however not been given much attention by most of the users interviewed in this study. Some of the experienced miniSASS users still rely on the most knowledgeable person leading the monitoring group to upload data on the Google Earth database. This indicated that sharing data using the Google Earth database was still a challenge. However, some respondents admitted to being familiar with both Mathuba and miniSASS Google Earth databases. Two respondents emphasised the strength of combining the two water resource monitoring tools for better water quality data. The Google Earth miniSASS database was developed by GroundTruth with seed funding from the Water Research Commission. Respondent B raised uncertainty about the existence of Mathuba, yet it was highly recommended by other respondents for complementing the miniSASS results.

The study revealed that out of ten respondents interviewed only six were actively uploading data on the miniSASS database. The Molweni schools, for example, rely solely on one person to upload data after each monitoring session. While this is still a challenge with most users, the Palmiet River Watch has shown innovative ways of using cell phones to take pictures and report their findings on a daily basis using WhatsApp. About two respondents perceived cell phone use in monitoring water quality as a much-needed intervention to leapfrog the absence of computers and internet access in rural areas.

5.2. 5 Forming partnerships for river health

Figure: 10 River clean-up by Eco-clubs

Source, DUCT, 2013

Other than conducting semi-structured interviews, document analysis assisted the researcher in gathering data addressing the research questions, especially on numerous interventions that have contributed in building capacity needed to tackle environmental degradation within uMngeni and Msunduzi catchments. It is evident that partnerships in the case of eThekwini, uMngeni and Msunduzi Municipalities have assisted in bringing communities closer to the pollution problems, spearheaded by the non-profit organisations WESSA and DUCT, with support from local consulting firm GroundTruth. While DUCT and WESSA are the champions of public participation on water-related projects in these catchments, the consulting firm GroundTruth provides the technical expertise in the development and rolling out of water quality monitoring citizen science tools. All the respondents interviewed for this study pointed out that they have either sought advice, had workshops with, or been employed by either WESSA or DUCT.

Within the uMngeni and Msunduzi catchments monitoring water quality has contributed to a growing number of citizen scientists, mostly amongst the youth, who volunteer their time towards river health.

Working with 227 schools along the Duzi and uMngeni Rivers has contributed to DUCT's vision for healthy rivers. WESSA, on the other hand, has numerous environmental programmes for schools which have been incorporated into their citizen science packages. miniSASS has been incorporated under DUCT and WESSA's Eco-Schools programmes. WESSA reported that since 2003 more than 10 200 schools across South Africa have participated in their Eco-Schools programme and 60 per cent of them have been sustained (WESSA, 2014). WESSA's Fundisa for Change programme empowers educators in teaching environmental issues. River health is strategically integrated into the school's programme for capacity building purposes.

Over the past eight years, DUCT reported to have worked with over 40 schools in citizen-based projects such as Adopt-a-River and miniSASS (DUCT, 2013). The school's initiatives are done to provide a practical understanding of environmental health issues to learners while linking it to the school curriculum. Apart from using miniSASS, DUCT's schools programme includes river walks, removal of alien invasive species in rivers, river clean-up days and River Care Teams (DUCT, 2013). Community-based monitoring is in line with the point noted by Hilchey (2011) that monitoring water resources using community groups benefits the community, government and species living in rivers and streams.

Testimonies from Respondent B indicated that she started working with miniSASS around 2000, and was connected through membership to WESSA and networked with river health scientists such as Jim Taylor (WESSA) and Mark Graham (GroundTruth) at the time of miniSASS development. Graham, *et al*., (2004) are of the view that every school, environmental or community group could potentially become a water monitoring cell. In fact, one could say this has already 'taken off' in uMngeni and Msunduzi catchments, given the work that is currently being done in the Molweni and Baynespruit.

The objective of using schools as part of water quality monitoring was pointed out during the interviews as providing the pillars for sustaining citizen science even in the absence of the coordinators. One respondent pointed out that she knows her involvement will still be sustained since the learners have already started building their own networks to sustain their participation in the governance of water resources in their areas.

5.2.5.1 Enviro-champs and Enviro-clubs

Water quality monitoring in uMngeni and Msunduzi catchments is strongly supported by community-based volunteers known as the 'Enviro-Champs'. The Enviro-champs comprise of representatives operating in the Edendale, Sobantu and Mpophomeni areas of Pietermaritzburg (DUCT, 2013). The Enviro-champs report any matter relating to 'spill' events to the municipality. DUCT supports their work by giving them a stipend for buying airtime, mainly for reporting purposes (DUCT, 2013). The Enviro-champs have contributed significantly towards the reporting of uncovered and overflowing sewer manholes located in the vicinity of these volunteers (Kolbe, 2014).

5.2.5.2 Eco-schools programme

The Eco-Schools programme is championed by WESSA and supported by the Department of Water and Sanitation. The Eco-Schools programme has contributed much towards the restoration of river health of Msunduzi and uMngeni catchments using miniSASS (see Figure 9 above). Currently, there are 1200 registered Eco-Schools subscribed to the programme to create awareness and drive environmental sustainability in schools (http://wessa.org.za/what-we-do/eco-schools.htm). In some of the schools along the Msunduzi and uMngeni catchments miniSASS has been integrated into the Eco-School's curriculum.

5.2.6 Lodge owners benefit from citizen science interventions

Respondent J emphasised the point that some lodges in South Africa are likely to be built closer to the catchments because of the aesthetic value water has for people. This view is supported by Palmer, *et al.,* (2002, p.36) as they confirm that good rivers exist in game parks where they are used for the tourism industry, with the potential to generate jobs. Monitoring of water quality by community-based groups has the potential to increase the growth of the country's economy as people get attracted to clean water for fishing for rare fish species and to satisfy spiritual needs in cleaner catchments. Noted in the *Highway Mail* published in one lodge owner along the banks of Palmiet in Cowies Hill admitted that the Palmiet pollution was the longest pollution event she had ever seen (Highway Mail, 19 December 2014). The lodge owner indicated that the image of her business was tarnished by the foul smelling and ugly looking foam that passed by her lodge.

5.2.7 Getting miniSASS methodology right

Emphasis was placed by Respondents A, B and D (interviews, 19 to 22 January 2015) on getting the miniSASS methodology right as of utmost importance in achieving useful water quality results. These respondents stressed that miniSASS users should familiarise themselves with some background information about the river; such as understanding what organisms you catch in the fast-flowing stream, what organisms you find on the side of the stream. Whoever is doing miniSASS needs to understand these basics. For example, if the holes in the nets are too big for some organisms one may miss some smaller organisms thriving in the stream.

All the respondents appreciated the educational value of miniSASS rather than focusing on the reliability of data. miniSASS is scientifically proven to give general water quality results that are equivalent to that of

SASS, which uses a far greater level of scientific detail. However, worrying about the reliability and validity of data should not be such a big concern, since miniSASS does not substitute the Department of Water and Sanitation's water quality monitoring programme.

Technology and the recording of data was an area of interest in this study. This was motivated by the fact that miniSASS has a web-based Google Earth database that allows users to make results from every monitored stream accessible for the whole world to see. Most of the respondents indicated that they have collected data but that uploading it on the database was not their area of expertise and that they rely on the scientists to assist. However, strong views were expressed on the advantages that the integration of technology brings.

Integrating technology into citizen science projects has raised participant interest, as explained by Dickenson, *et al.,* (2012). This intervention takes advantage of the already available tools such as smartphones, Facebook, Twitter, photo upload tools, tablets and many more, to make data accessible to a wider audience. Concerns were raised during the interviews that a number of households in South Africa still do not have access to electricity which jeopardises the use of computers, and that the cell phone advantage then should be considered for water quality monitoring. Also, rural areas cannot be expected to contribute at the same level as urban areas since Internet access is a challenge in rural areas.

The Palmiet River Watch has, interestingly, taken advantage of technology use to monitor the pollution of their catchment. About 250 residents are monitoring the catchment using photo uploads, WhatsApp and emails to share their observations. According to the respondent this technology use has made reporting faster and makes reporting to the eThekwini Municipality a quick process.

5.2.8 NGO sector strengthening citizen science

In KZN there is strong leadership displayed by the NGO sector in championing citizen science. As indicated earlier WESSA and DUCT have dedicated community-based environmental programmes in Msunduzi and uMngeni catchments. These programmes are supported by voluntary groups or based on stipends.

A group of concerned canoeists in KZN led to the formation of what is today known as the Duzi uMngeni Conservation Trust (DUCT), which was established in 2005 and became a formally registered non-profit organisation in 2006. DUCT's offices are situated in Pietermaritzburg. This NGO has contributed significantly by championing the health of the Msunduzi and uMngeni Rivers (DUCT, 2013). Apart from using miniSASS in monitoring the health of these rivers, DUCT also runs numerous citizen science programmes such as River Care Teams, Invasive Alien Weed Control, Eco-furniture, Land Care, Monitoring of Sand Mining, uMngeni River Walk from Source to Sea, River Clean-up Days, Working with Schools, Sewage Monitoring, Enviro-Champs and the Durban Green Corridor (DUCT, 2013). DUCT is home to the famous Dusi Canoe Marathon that takes place annually over 120 km between Pietermaritzburg and Durban. The canoe groups have been joined by experienced environmentalists and scientists committed to pollution-free waterways.

DUCT has formed strong partnerships while working towards achieving good water quality in the uMngeni and Msunduzi catchments. The partners are the Department of Environmental Affairs, eThekwini Municipality, Durban Green Corridor, KwaZulu-Natal Canoe Union, National Lottery, uMgungundlovu District Municipality and WWF Nedbank Green Trust, while working towards improving the water quality of the uMngeni and Msunduzi Catchments (DUCT, 2013).

As indicated earlier, water quality is a ‘wicked’ problem in Durban and Pietermaritzburg’s water resources. DUCT has prioritised, amongst others, to patrol main bulk lines by looking for spills. This action led to the approval of R400 million towards the upgrading of Darville Sewage Works and the city’s main sewage infrastructure (www.duct.org.za). DUCT also lobbies for the removal of solid waste from the rivers. This is made possible through the 100 long trash booms with the capacity to lift up heavy waste dumped in rivers such as the carcasses of dogs and goats (www.duct.org.za). Significant improvements have been realised by DUCT’s river health initiatives. The DUCT chairman David Still confirmed that municipalities and government departments are beginning to take river health seriously. Budgets are now being allocated by the relevant authorities for sewer upgrades and upgrades of sewage treatment plants, for alien invasive plant removal and for improved land care in general (DUCT, 2013).

5.3 Summary

In the uMngeni and Msunduzi catchments advancements have been made in implementing various citizen science projects. Citizen science interventions have led to tangible action taken by municipalities and it has been noted by DUCT that budgets are now being allocated to address river health problems identified in some cases this is based on poor water quality evidence from miniSASS experiments. Although not all the respondents provided perspectives and experiences encapsulating 15 years of citizen science usage as indicated in the purpose of the study, the researcher still managed to gather rich data based on the active use of miniSASS since its formal inception in early 2000. miniSASS has assisted in improving the management of water resources in KZN. A network of miniSASS users has already been established in KZN and is growing at high speed, extending to both urban and peri-urban areas of KZN.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1. Introduction

The water quality in uMngeni and Msunduzi Catchments is affected by the pollution challenges due to industrial pollutants, raw sewage flowing directly into the streams resulting in sewer charges (Dent, 2010), informal settlements with no toilet facilities, and the general illegal waste disposal from residential areas. While these catchments suffer from high levels of pollution, these catchments are sources of water to the neighbouring municipalities Msunduzi, uMngeni and eThekwini and they are also known for the prominent water sport, the annual Duzi Canoe Marathon supported by a number of fans. The sport already has economic benefits to the areas of Durban and Pietermaritzburg which has to be sustained by the maintenance of clean river systems.

Despite many factors contributing to the contamination of water resources in these catchments, citizen science has played a role in keeping the rivers, streams, dams and estuaries pollution-free.

The purpose of this study was to explore the perceptions and experiences of the users of miniSASS in the Msunduzi and uMngeni catchments. Over the past 15 years, the province of KwaZulu-Natal has been at the forefront of working with community groups in river health projects

This chapter presents the conclusions and additional insights from the study and also gives recommendations for further research. The study aimed at understanding the perceptions and experiences of users of miniSASS, a citizen science tool that has widely been used in KZN to monitor the quality of rivers and streams. The study sought to answer the question "How has miniSASS been perceived and experienced as a citizen science tool in uMngeni and Msunduzi catchments?" While using a qualitative approach, semi-structured interviews with ten participants assisted in gathering data to answer the three questions raised earlier in this report. The study objective was to explore if there is any value attached to the use of citizen science tools and interventions in polluted catchments.

6.2 Conclusion

In this chapter the researcher gives the conclusions drawn from the research findings based on the data presented in chapters four and five presented earlier.

6.2.1 Environmental knowledge

Citizen science in uMngeni and Msunduzi catchments has already started building local capacity needed to support the work done by the municipalities and the Departments of Water and Sanitation and Environmental Affairs. In doing so, through the support of the local NGOs WESSA and DUCT miniSASS has practically been integrated into the river health initiatives as the main tool used to assess the quality of the rivers. miniSASS has formed part of the school's programmes currently active in river health in Msunduzi and uMngeni catchments. Through miniSASS involvement learners, as future citizens, are equipped with knowledge about their environment which makes it sustainable.

6.2.2 Raising the 'red flag'

In both uMngeni and Msunduzi Catchments there are a number of instances where the use of miniSASS, Mathuba program, IHI and chemical analysis has pointed to the sewer leaks, pipe bursts, spilling sewage manhole and caused municipalities and the government departments to immediately address the problems. All the interviews held in this study pointed to the cases where the problems were identified and reported to the municipalities. The purpose of doing miniSASS should generally be based on creating awareness about the need to keep the rivers clean.

Respondents I (interview, 30 January 2015) mentioned that miniSASS is considered as providing support to the Deputy Minister of Water and Sanitation’s Adopt-a-River programme that is driven mostly by the regional offices. The Adopt–a-River programme focuses mainly on river clean-ups with a stipend attached to it. The contrast is that in urban areas river clean-ups are voluntary whereas in rural areas the involvement means getting a stipend due to the high poverty levels of participants.

The involvement of citizens helps in highlighting the underlying causes of the problem that authorities may not be fully aware of. For example the Enviro-Champs of Mpophomeni have helped to highlight the fact that inadequate infrastructure is to blame for the sewage that flows from the township into Midmar Dam.

6.2.3 miniSASS data and river health monitoring

miniSASS data is currently not officially considered by the DWS for monitoring water quality in the rivers. The official national monitoring programmes considered for reporting purposes are the scientific data management programmes such as FAII (fish assemblage integrity index), SASS 5 and RAM (Rapid Assessment Method). Depending on the availability of accredited regional personnel, the regions are expected to provide full ecostatus of the rivers being monitored. miniSASS plays a role in creating general awareness, and when citizens pick up something they report the finding to the Department’s accredited official. Respondent J from the DWS indicated that in cases where the regions do not have, for example, SASS 5 accredited people, miniSASS may be considered, but this is entirely up to the region to decide.

The reliability of citizen science was not a big concern to the respondents. Most of the points mentioned touched on the importance of the educational value that citizen science tools offer rather than the accuracy and authenticity of data. Of great importance is the fact that citizens become aware of the tools at their disposal rather that worrying too much about data. All the respondents confirmed that the focus should rather be on mobilising communities to get involved and interested in the environment. One respondent mentioned that South Africa cannot be compared to the developed countries like Canada that have well-defined water quality monitoring cells for the public because the priorities of developing countries may not necessarily be the same. Of concern to the other respondent was the knowledge that is still lacking. People should understand why they should monitor, what it means to them, what it means to the country and our neighbouring countries and what value it brings to them.

Other respondents were concerned with the credibility of minisass data and indicated that they would feel confident about the results only if an experienced scientist presided over the sampling. While interviewing a respondent from the Molweni School's River Health Project, he confirmed that miniSASS is always done in the presence of an experienced scientist to ensure reliable data is obtained. Respondent D appreciated the manner in which a GroundTruth scientist demonstrated the sampling procedure on two occasions when they were doing monitoring with the schools.

6.2.4 Technology and river health monitoring

Although technology use has not been used to its full potential in uMngeni and Msunduzi catchments, the use of cell phones was perceived as a breakthrough in monitoring water quality. During the interviews the respondents expressed keen interest to see the cell phone apps that could help break the access barriers created by the rural– urban divide. Access to the internet for example is not so easy in rural areas where piped water supplies are still lacking and cell phone use may be a key tool according to the respondents.

6.2.5 Social learning

The study posed a question to all the respondents on how they see social learning happening as they use miniSASS with the groups. Meaningful learning was strongly emphasised from the interviews. miniSASS gets introduced to the schools by the scientists as a contributory project that creates excitement and enthusiasm amongst the users. Of great interest from the interviews was to understand how the citizen science coordinators avoid the use of technical jargon (the use of complicated terms related to invertebrate species) in order to draw interest from the learners.

When miniSASS sampling sessions were conducted with schools, learners were grouped according to where they came from. However, Respondent D mentioned the understanding that water does not have borders; learners need to work together and solve the current challenges. An example of this is Mbali, a learner from Mpophomeni who approached other students from KwaMevana High School to form a team that was going to present to uMgungundlovu Municipality the need to sustain the river health projects that they had started. According to Respondent D, the learners have developed a sense that the environment does not have borders and they don't need to compete as schools. This idea of unity was also supported by the existence of the Enviro-champs in their communities.

Citizen science language was emphatically mentioned by Respondent D as the key component that she observed developing while working with learners over a long period in Mpophomeni and KwaMevana Township. The respondent referred to growth related to the concepts and technical terms, showing deep understanding of water pollution and a proficiency in expressing themselves as water stewards. Additionally, the feedback the respondent received from the educators related to the manner in which the knowledge derived from the ability to use the miniSASS dichotomous key and their learning in the Life Orientation classes contributed to their development.

6.2.6 Citizen science and economic value

During the interviews at least two respondents mentioned the value attached by the lodge owners to clean rivers in South Africa. According to the Respondent J there is no doubt that citizen science efforts such as river clean-ups and water quality monitoring can help improve the habitat of some of the rare species of fish which indirectly attract tourists to stay just for fishing purposes. If public participation leads to clean rivers, there is potential for economic growth. Rivers are a natural asset to the country. A lodge selection is sometimes influenced by the availability of certain fish species found in rivers, such as the yellowfish in South Africa.

People come as far as Scotland; those that love fishing a lot would travel from Americas and from all over the world just to catch fish in South Africa. Some would be more specific, they would say they want to fish kimberleyensis, which are very scarce and difficult to catch. They come to fish because of the attraction brought by yellowfish to their facilities. The Palmiet River Watch also saw the excitement of one of the lodge owners in Cowies Hill who indicated that the pollution along the Palmiet made a bad impression on guests from Canada who had a wedding reception party (Highway Mail, 19 December 2014).

In conclusion, the findings of this study is that miniSASS is perceived as a valuable educational tool in Msunduzi and uMngeni catchments which has led local government authorities to respond faster in solving incidents of industrial pollution; address poorly maintained water infrastructure and fix the leaking sewers contaminating water.

7. Recommendations

The study recommends that an investigation be made on the economic value of citizen science contribution in KZN since there were indications from the interviews that it has already benefited some of the accommodation businesses. The users of citizen science tools for community-based monitoring of water resources quality can assist in addressing water pollution problems currently experienced in catchments. As the Water Affairs Portfolio Committee recommended in 1996 that people living close to the watercourses need to be brought in to manage the persistent pollution. The study shares the same sentiment that water monitoring at local level needs to be strengthened. Communities need to be more involved in reporting pollution problems as water is increasingly becoming a scarce resource in KZN and other parts of South Africa.

The seriousness of river health problems has shown that the Departments of Water and Sanitation and Environmental Affairs, as well as the municipalities, are practically not able to monitor all the country's watersheds. However, they can redesign their water monitoring systems to be more collaborative such that community-based initiatives work in their favour. As the water quality monitoring networks grow, the government departments begin to trust citizen science as a collaborative approach rather than an antagonistic approach of trying to address river health.

In uMngeni and Msunduzi catchments miniSASS has brought about meaningful change, firstly, of understanding the environment, and secondly of realising that communities themselves can contribute toward solving the pollution problem. I agree with one of the respondents who emphasised the need of making communities understand why they should monitor the quality of water in their rivers, what it means to their areas, their country and to the neighbouring countries.

8. Need for further research

It would be interesting to know how miniSASS influences the learners to end up in careers as scientists or whatever career path they chose to follow. We need to understand how their involvement has positively influenced their academic choices. As one of the respondents indicated that feedback from teachers has shown that learners are growing in stature as leaders, and in classes are also showing far more interest in their subjects because they have seen it 'out there' and they are making a connection. It would be interesting to investigate how miniSASS use has made the learners more capable and interested in their studies and also other contexts they find themselves in. Further research needs to focus on the stories of learners who were involved in miniSASS from its inception. As indicated above it would be interesting to further understand the economic value of citizen sciences contribution for example, in the tourist accommodation businesses who appreciated the change in terms of water quality of the nearby streams.

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APPENDIX

INTERVIEW GUIDE USED 19 JANUARY – 30 JANUARY 2015

1. Tell me briefly about yourself.
2. Tell me briefly about what attracts you to water quality monitoring.
3. Are you part of any organised structure/organisation for water quality monitoring? How?
4. How long have you been involved in river health initiatives?
5. What/who inspired you to pay attention to the water resources/water quality?
6. Have you done miniSASS? How often do you do miniSASS in your catchment?
7. What have you done so far to address problems in your rivers /streams?
8. Who do you work with as you try to solve the water quality problems?
9. Which specific rivers /streams have you worked on so far? How were the conditions when you started? Have you seen any noticeable improvements in your rivers /streams since you started?
10. What is done in your organisation/ forum/conservancy to support river health?
11. Have you ensured that other people in your community are trained in using the river health tools?
12. Explain how this monitoring has been sustained over the past years.
13. When citizens get involved in monitoring water quality how do you encourage them to do proper sampling for getting reliable data?
14. Who receives miniSASS data from your catchment?

15. Is there any feedback that is given to you or your monitoring groups after submitting miniSASS data to the responsible authorities?
16. When looking at the issue of reliability, validity, quality and accuracy of the samples taken by monitoring groups using miniSASS, should we trust data derived from them?
17. Has the data collected by community members been used meaningfully in your catchment? And if so by who and for what purpose?
18. Have you and your group /forum had a chance to meet the decision makers to discuss water issues affecting your catchment?
19. When your river scores poorly on a miniSASS assessment tool what does it mean to you? What actions do you take to address the problem?
20. Have you taken any action based on the poor results from the miniSASS assessments before?
21. Have you worked with government authorities in addressing problems polluting your rivers? How?
22. As you monitor the river health, have you spotted the source of pollution?
    - If so, what have you done about it?
23. Is miniSASS empowering you and your group to raise your voice in governance structures in your municipality?
24. Do you think assessing the biological indicators of water quality is sufficient to test the water quality in rivers and streams?
25. Are you happy with the manner in which the miniSASS is being rolled out currently in your area?
26. Do you think community members are well positioned to carry our water testing and monitoring of watersheds?
27. Has technology use been integrated into the manner in which you monitor water quality in your catchment?

28. Has technology applications changed the way in which your data is collected as compared to the past?
29. Do you and your group use the miniSASS Google Earth database for sharing data with other people?
30. Probe: If not, how are you planning to take this into consideration in future?
31. How do you design projects for community involvement when doing water monitoring? Which one better describes the manner that you design your projects co-creation, collaboration or contribution?
32. In your opinion does learning take place in the process of data collection? (Why would you say so and how are participants learning according to your observation?
33. Group identity – do monitoring groups share common goals as they monitor rivers/streams? How so?
34. If you were to predict the future of this catchment in years to come (looking at what is happening now), what would you say?
35. What do you think should be done by government to inspire communities to take part in water quality monitoring in your catchment?
36. How has citizen's involvement in data collection assisted in improving the manner in which our water resources are governed in your catchment? What notable actions are there?
37. Having tested the water quality several times and noticed problems, do you think this practice gives you a voice leading to solutions by responsible authorities?
38. Do you perhaps think the new technologies such as cell phones, tablets, computers etc. have a role to play in speeding up and improving water quality monitoring and management of our rivers?
39. How can a national roll-out be best supported in your opinion?
40. In your opinion what networks can be developed and mobilised?

41. What training support would be most effective?

42. How can management practices be linked to miniSASS field-work practices?

43. To what extent does miniSASS support a 'line-of-site' towards tangible action?