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Social change innovations, citizen science, miniSASS and the SDGs

Jim Taylor [a,*], Mark Graham[b], Adrienne Louw[b], Ayanda Lepheana[b], Bonani Madikizela[c], Chris Dickens[d], Deborah V. Chapman[e] and Stuart Warner [e]

[a] University of KwaZulu-Natal, Centre for Water Resources Research, Pietermaritzburg, South Africa
[b] GroundTruth, Hilton, South Africa
[c] Water Research Commission, Pretoria, South Africa
[d] International Water Management Institute, Colombo, Sri Lanka
[e] UN Environment Programme GEMS/Water Capacity Development Centre, School of Biological, Earth & Environmental Sciences and Environmental Research Institute, University College Cork, Cork, Ireland
*Corresponding author. E-mail: jimtaylor835@gmail.com

JT, 0000-0002-5461-1582; SW, 0000-0002-2626-2784

ABSTRACT

The United Nations Sustainable Development Goals (SDGs) describe a course of action to address poverty, protect the planet and ensure prosperity for all (https://sdgs.un.org/goals). More specifically, SDG 6 clarifies how water quality, quantity and access are crucial to human well-being, and yet human activities are compromising water resources through over-exploitation, pollution, as well as contributing to the spread of disease. Globally aquatic ecosystems are highly threatened and concerted efforts by governments and civil society to 'turn the situation around' are simply not working. Human-created problems require human-centred solutions and these require different ways of thinking and acting to those behaviour patterns that are contributing to the challenges. In this paper, we first consider *causal* approaches to attitude change and behaviour modification that are simply not working as intended. We then explore *enabling* responses such as citizen science and co-engaged action learning as more tenable alternatives. SDG 6 has a focus on clean water and sanitation for all. The SDGs further clarify how the extent to which this goal can be realized depends, to a large extent, on stakeholder engagements and education. Through stakeholder engagements and educational processes, people can contribute towards SDG 6 and the specific indicator and target in SDG 6.b – Stakeholder participation. Following a three-year research process, that investigated a wide range of participatory tools, this paper explores how the Stream Assessment Scoring System (miniSASS; www.minisass.org) can enable members of the public to engage in water quality monitoring at a local level. The paper continues to demonstrate how miniSASS can contribute to the monitoring of progress towards Sustainable Development Goal Target 6.3, by providing a mechanism for data collection indicator 6.3.2. miniSASS is proving popular in southern Africa as a methodology for engaging stakeholder participation in water quality monitoring and management. The technique costs very little to implement and can be applied by children and scientists alike. As a biomonitoring approach, it is based on families of macroinvertebrates that are present in most perennial rivers of the world. The paper concludes by describing how useful the miniSASS technique can be for addressing data gaps for SDG 6.3.2 reporting, and that it can be applied in most regions of the world.

Key words: Biomonitoring, Citizen science, miniSASS, SDG6, Water quality

HIGHLIGHTS

- The Sustainable Development Goals (SDGs) are a globally approved policy and action process.
- This paper demonstrates how citizen-derived data through the stream assessment scoring system (miniSASS) can be used for SDG 6 reporting on water quality.

- It explores the expansion of miniSASS to collect water quality data globally.
- miniSASS supports policy by mobilizing society to engage with water issues.

INTRODUCTION

Conventional wisdom continues to fail us

Conventional wisdom approaches, which often emphasize attitude change with the assumption that behavioural practices will follow have not proved tenable (Beck, 1992, 1995, 1997; Kemmis & Mutton, 2012). Fien (2003) emphasizes that 'among the most successful [environmental education] programmes are those that avoid the belief that awareness leads to understanding, understanding leads to concern, and concern motivates the development of *skills and action* (our italics)' (Fien, 2003). Causal, linear, top-down or centre-to-periphery approaches that assume behaviour change, following awareness raising, often facilitate a power-gradient from those who feel they know to those who they feel ought to know. This rational logic continues to assume that once informed, the others, often described as a target group[1], will change accordingly! As reported above, this rational change process fails to meet expectations and, at times, may even alienate the very people it is seeking to change (Taylor, 2010).

The sustainable development goals and SDG 6

SDG 6 has a focus on clean water and sanitation for all. The SDGs further clarify how the extent to which this goal can be realized depends, to a large extent, on stakeholder engagements and education. Through stakeholder engagements and educational processes, people can contribute towards SDG 6 and the specific indicator and target in SDG 6.b – Stakeholder participation, namely:

> 'Support and strengthen the participation of local communities in improving water and sanitation management'

The United Nations (UN) are explicit as to why stakeholder participation is important, but a key research question is how this participation can be meaningful and engaging, particularly the aspect of improving water management:

> '*Target 6.b aims for the participation of local communities in water and sanitation planning and management, which is essential for ensuring that the needs of all people are being met. The involvement of relevant stakeholders is further necessary to ensure: that the technical and administrative solutions decided upon are suitable for specific socioeconomic contexts, the full understanding of the impacts of a certain development decision and the encouragement of local ownership of the solutions when implemented (to ensure sustainability over time). Target 6.b supports the implementation of all SDG 6 targets (targets 6.1–6.6 and 6.a) by promoting the meaningful involvement of local communities, which is also a central component of IWRM*'[2].

A detailed three-year research process, supported by the Water Research Commission, investigated a wide range of public participation approaches to water quality issues and clarified how citizen science can play a

[1] The use of the term target group, a metaphor from military operations, emphasizes the causal tradition of 'getting the message across.' It is therefore difficult to apply in a more inclusive, dialogue-centred manner. By classifying people as 'the other' it militates against an opportunity for relationship building, mutual learning, deliberation and a commitment to building understanding and human dignity.

[2] https://www.sdg6monitoring.org/indicators/target-6b/

meaningful role in water-related issues (Graham & Taylor, 2018). Of all the citizen science tools that were reviewed, miniSASS stood out as a relatively easy technique to use, that can be applied at virtually no cost, the results are immediately available and no laboratory is necessary to develop or interpret the findings.

Stakeholder participation through citizen science

Citizen science and co-engaged action learning (Bonney *et al.*, 2009; Pocock, *et al.*, 2014; O'Donoghue *et al.*, 2018) are, however, showing the way to more inclusive, enabling and effective social change processes. This work deepens the understanding of water issues in a practical and applied manner and enables actions for more sustainable practices (Graham & Taylor, 2018). Here the democratization of science engages people who often become proud and eager participants in building understanding and working for more sustainable practices rather than being the passive recipients of knowledge from others.

For challenges as complex as water management and ecological infrastructure[3], the importance of context and the involvement of those participating is crucial. Many of these issues and problems require the integration of knowledge from the natural and social sciences, as well as economics, and there is rarely a single 'silver bullet' solution. As Bhaskar *et al.* (2010) states, 'exemplifying the triangular relationship of critical realism, interdisciplinarity and complex (open-systemic) phenomena' is needed for the investigation of such wicked problems as water resources management.

As stated above 'The democratisation of science, through citizen science processes, supported by practical and accessible 'tools of science,' is one area of work that is showing encouraging results' (Graham & Taylor, 2018, page V). Building collective capacity in the context of resource-based risks and uncertainty points towards the broad field of social learning (Wals, 2007) as a useful component of effective social change. These ideas and concepts form the basis of this paper which advocates an 'enabling' orientation – rather than a traditional 'causal' approach (i.e. seeking to cause a change in others through top-down methodologies) (Taylor, 2014).

miniSASS, biomonitoring and Google Earth

We now explore miniSASS as a key enabling tool that may have global relevance in both mobilizing people, popularizing the Sustainable Development Goals (SDGs) and helping provide accessible biomonitoring data, at virtually no cost to the user, towards SDG indicator 6.3.2. This perspective on citizen science is mirrored in a seminal paper by Fritz *et al.* (2019) on citizen science and the United Nations SDGs. In their paper, Fritz *et al.* develop a road-map on how citizen science can support the SDGs. In keeping with this theme, we are exploring miniSASS as a complementary, citizen science orientated, research tool.

What is the stream assessment scoring system (miniSASS)?

miniSASS is a simple tool which can be used by anyone to monitor the health of a river. One simply collects a sample of macroinvertebrates (small organisms large enough to be seen with the naked eye) from a natural river or stream, and depending on which groups are present, one can calculate a River Health Index for the river. This score helps classify the health, or ecological condition of the river, ranging across five categories from natural (blue) to very poor (purple). The results can then be recorded on the miniSASS website Google Earth layer (www.minisass.org). This database is effectively a 'Living data' system where further data can continuously be added. Through miniSASS, one can learn about rivers, monitor their water quality, explore the drivers of water quality deterioration, and, of course, take action to improve the quality of the streams and rivers.

[3] Understanding the importance of ecological infrastructure (EI) which may be defined as *functioning ecosystems that produce and deliver valuable services to people* (Jewitt *et al.*, 2020), may be a broader and more useful term to help understand catchment management processes.

Challenges to be considered when applying miniSASS

As with any scientific enquiry processes, a number of challenges must be addressed when applying miniSASS, these include:

- Participants must locate a local stream or river and be prepared to go into the water to locate the organisms.
- The organisms are not always easy to catch for identification purposes. A small net, such as one used for a goldfish pond, can be helpful here.
- Once collected, the organisms need to be identified. This is not always easy. The miniSASS website, at www.minisass.org, does, however, provide a simple dichotomous key through which the users can key-out the organism they are seeking to identify.
- In any citizen science, endeavour issues of scientific accuracy are a concern. By offering people training courses in miniSASS, this issue is alleviated to some extent. Training can be undertaken online using a simple, instructional video from the miniSASS website referred to above. The validity of the data will be taken up further in the Results and Discussion section.

Where did miniSASS come from?

miniSASS (Graham *et al.*, 2004) was derived from the more rigorous South African Scoring System (SASS), a biomonitoring method for evaluating river health (Dickens & Graham, 2002; Dallas & Day, 2004). The SASS method requires the ability to identify up to 90 different aquatic invertebrate families and thus a high level of training is required. There was, therefore, a need for a simpler, more user-friendly tool for biomonitoring that would still yield reliable water quality/river health data. This need gave rise to the development of miniSASS. The development process involved reducing the taxonomic complexity of SASS by creating broad groupings of invertebrates that could act as surrogates for the complete suite of SASS taxa. A rigorous statistical evaluation of a large volume of data from the SASS method was conducted in order to determine whether the miniSASS method would yield viable results, similar to those derived from SASS. This evaluation assessed data collected over a wide geographic and water quality range and provided indications that miniSASS is suitable for predicting SASS scores and is thus an appropriate indicator of biological water quality (Graham *et al.*, 2004).

The strength of miniSASS has been evident for several years. Its use is widely applied in South Africa, where it was initially developed, although it has been successfully used in many other southern African countries. It has been effectively applied in India (in the Himalaya mountains at over 18,000 feet in altitude), in Vietnam, Canada (where the ambient air temperature was −20°C), Germany and Brazil. GroundTruth, an environmental engineering company, verifies the incoming data and has worked with the Water Research Commission to support this development through the www.minisass.org website. A topical feature of this website is the number of recent additions of data, as shown on the right-hand side of the screen. miniSASS is also found on the Water Research Commission's website www.wrc.org.za.

RESULTS AND DISCUSSION

The existing and future potential of miniSASS as a global citizen science monitoring tool suitable for SDG 6.3.2

Substantial development of miniSASS has taken place since its early inception. This work includes the development of an online portal, or website described above, that allows participants, ranging from school children to NGOs and other organizations, to upload their self-collected data. Although there may be concern about the validity of these data, largely due to a lack of training of those collecting it, this concern is offset by the fact that the data are 'crowd-sourced', allowing for the shear bulk of evidence to tell a valid story, perhaps even more reliably than the more sparsely collected 'official' data. Holt *et al.* (2013) describe and demonstrate the potential of citizen science data. They show that, despite biases, it is possible to statistically clean citizen science data so that it matches the quality of professional sampled data. Citizen-derived data can also cover huge geographical regions, whereas professionals can only cover small areas (due to the cost).

How universal is miniSASS?

Because many macroinvertebrates have part of their life cycle in the water and part in the air, they have been able to move vast distances, carried by water, wind and by ducks and other vectors, and are thus found spread across the world[4]. However, others, such as some crustaceans, have not moved so far and tend to be more confined. For this reason, macroinvertebrate samples collected across the world have many similarities, especially at the taxonomic level of order or family, while at a local level, there is plenty of division into local genera and species. For this reason, indices that are based on the higher taxonomic level of order and family are more globally applicable. This was validated, in South Africa, and was a large part of the success of the SASS index (Dickens & Graham, 2002) which is based largely on family identification, making the index inexpensive and thus affordable for routine and large-scale monitoring.

An index that is to be applied at a global level could be improved with local adaptations. This can be done, not only to add or subtract orders or families but also to verify the sensitivity of the groups. Such adaptation could be done at an 'eco-region' level, for example, all northern cold-water European countries are likely to have similar invertebrates, which will need to be separated from the African ones which will also be separate from the Asian ones. We are finding that the differences are relatively minor, however, and a single index that includes the orders and families most important for ALL regions of the world, is viable as a citizen science instrument. A generalized and indicative global index, using the miniSASS methodology, is thus possible for citizen scientists.

miniSASS has many strengths, as well as a number of challenges. These are tabulated in Table 1.

A summary of SDG indicator 6.3.2 methodology

SDG indicator 6.3.2 is reported by countries as the *proportion of bodies of water with good ambient water quality*. It is one of two indicators of Target 6.3 which aims to improve the quality of water in rivers, lakes and groundwaters by reducing pollution. Level one monitoring of the official indicator methodology (UN Water, 2018) relies on water quality data from *in situ* measurements and the analysis of samples collected from rivers, lakes and aquifers. Water quality is assessed by measuring physical and chemical parameters that reflect natural water quality, together with major human impacts on water quality. Level two reporting can include any type of water quality data that can be used to classify a body of water. Examples include data from citizen initiatives, Earth observation products, biological approaches or additional water quality parameters are not included in the core Level one list.

The indicator methodology stipulates that countries are divided into river basin-based reporting districts, which are further divided into smaller water body units. These small hydrologically defined units are classified based on the results of measurements of five core parameter groups: oxygen, salinity, nitrogen, phosphorus and acidification. These data are compared to numerical target values, and if a compliance rate of 80% or more is achieved, a water body is classified as having 'good' ambient water quality.

[4] We have been told that macro-invertebrates pre-date the dinosaurs and that their ancestors were present on the mega-continent, *Pangea*, before it split up (*Pers. Com*. Prof. Bruce Rubridge, Palaeontology, University of the Witwatersrand wits.ac.za). This offers an alternate explanation as to why one finds similar macro-invertebrates, which can be used as indicator species, in most perennial rivers of the world!

Table 1 | miniSASS strengths and challenges.

Strengths	Challenges
It supports the global trend to engage citizen science. This is especially relevant for realizing SDG 6 (b).	Participants need to learn how to do miniSASS. Although there are simple instructions and tutorials on the website, participants learn best in the field with an experienced person.
Crowd-sourced data have its own unique validity; while each sample may not have a high level of confidence, the sheer number of data records strengthens the research rigor.	Citizen science by nature requires a level of coordination. At present, the coordination is provided by Ayanda Lepheana and *GroundTruth* with website support from SAIAB[a] and SAEON[b], both South African government-supported institutions. If the miniSASS data are to be used for SDG reporting globally, it will require additional support.
The approach engages citizens with the SDG agenda, enabling them to contribute to a global effort. This could become a VERY big promotion for the SDGs.	Approval of data by the government may be challenging if the government prefers to 'be in charge' and not receptive to citizen science input and participation. To what extent will governments embrace and support the democratization of science?
miniSASS data have been used to demonstrate citizen science participation in monitoring compliance with water quality objectives.	Each country will have the ability to either embrace citizen science to its fullest, or for government officials to use the method themselves as a low-tech monitoring method. While the latter is not invalid, it is unlikely that it will result in the high number of data that will be collected by a strong citizen science programme.
The miniSASS data management system allows for the clustering of the data into a time-series. This means progress over time can be measured and compared at the same site.	
miniSASS costs very little to use. Simple apparatus such as a net, which can be home-made, and a reference sheet that is available as a free down-load, on the website, strengthens the miniSASS study.	
Since the macroinvertebrates are visible to the naked eye, the shape and form are of most importance. This means that advanced competence in languages such as English is not essential. Indeed, nine-year-old isiZulu speaking children are able to master the technique. miniSASS materials are also available in other languages such as French, Afrikaans and isiZulu.	

[a]South African Institute for Aquatic Biodiversity http://www.saiab.ac.za.
[b]South African Environmental Observation Network.

Case study: using miniSASS data to generate an SDG indicator 6.3.2 score

In many parts of the world, there are significant data gaps, both spatially and temporally, in the water quality record which cannot be filled using 'conventional monitoring programmes'. Citizen science projects are one of several approaches currently being explored to see whether they can play a significant role in filling these data gaps.

The miniSASS data generated by citizens do not fit the requirements of Level one reporting for SDG indicator 6.3.2 as they are based on a biological assessment, rather than physico-chemical data collection, and are not sampled at fixed monitoring locations. In this study, an indicator 6.3.2 score was generated that could be described as a 'Level two report' based on the current methodology (UN Water, 2018).

In order to calculate an indicator score, a data-rich area was selected as shown in Figure 1. The Department of Water and Sanitation of South Africa defines drainage basins for water resource management purposes. The case study area aligns with Drainage Basin U. River water bodies were defined using the HydroATLAS Level 10 units (Lehner & Grill, 2013) and a total of 129 river water body units were defined for the drainage basin. Each miniSASS data record was allocated to a water body unit based on spatial location, and the scores compared to the Fair/Good boundary of the ecological categories for the two river types ($\geq$5.9 for sandy-type rivers and $\geq$6.2 for rocky-type rivers). A water body was classified as 'good' if 80% of samples met this target.

In order to calculate the SDG indicator score, the proportion of water bodies within the basin with good water quality were calculated. Of the 129 river water bodies defined, 40 had miniSASS monitoring data and 6 of these were classified as 'good'. This thus yielded an SDG indicator score of 15 for this basin ($6/40*100 = 15$).

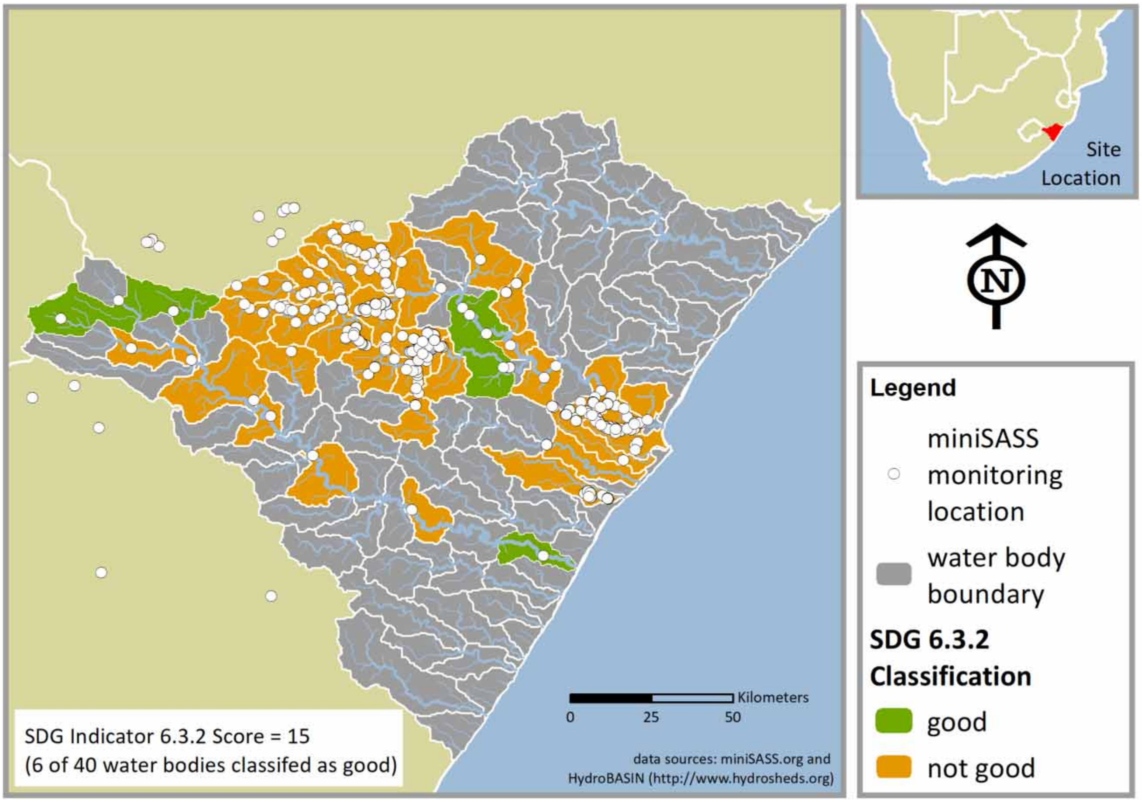

Fig. 1. | Example of miniSASS-generated SDG indicator 6.3.2 score for a single drainage area, in KwaZulu-Natal, South Africa.

One key finding of this analysis was that the monitoring effort differed considerably between water bodies. The most data records for any single water body were 183, whereas several had only a single record. This disparity in monitoring effort results in some water bodies being classified with a much higher degree of confidence compared to others. A further development of this method could include specifying a minimum data requirement to ensure that water bodies are classified equally and reliably. In this example, setting a minimum data requirement of five monitoring records per water body resulted in 17 water bodies being monitored, none of which were classified as 'good'. In addition to defining minimum data requirements, future testing could include optimizing monitoring network design to improve data collection coverage.

miniSASS as a proxy for formal water quality monitoring programmes

Much of the strength of miniSASS lies in its ability to generate large amounts of data through citizen science and crowdsourcing. Although these data may not always be entirely valid, due to the fact that many of the people who collect it may not have received formal training, it has its own unique validity as the sheer number of data records strengthens rigour (Holt, *et al.*, 2013). In order to assess the ability of miniSASS to act as a proxy for formal water quality monitoring programmes, miniSASS data were compared against data collected by the River Ecostatus Monitoring Programme (REMP). The REMP assesses the ecological condition of South Africa's rivers based on a rapid assessment of aquatic macroinvertebrates, using the Macroinvertebrate Response Assessment Index (MIRAI).

The 2017/2018 REMP data were compared against the miniSASS data collected for the same time period. In 2017 and 2018, a total of 522 miniSASS data entries (234 and 288 in each year, respectively) were recorded across South Africa. Of these, 13 were recorded within a 500 m radius of a REMP monitoring point and 98 within a 5 km radius (Figure 2). However, only 28 REMP sites within 5 km of miniSASS sampling points and 11 within 500 m of miniSASS sampling points had REMP data recorded during this time. Of the 11 miniSASS entries recorded within 500 m of REMP monitoring sites, four yielded the same ecological category as those reported at the REMP sites, three yielded an ecological category one category below those reported at the REMP sites, and the remaining four yielded ecological categories two categories below those reported at the REMP sites. The frequency of samples recorded in each ecological category by the REMP and miniSASS data collection is presented in Table 2.

Although the results assessed here do not provide conclusive evidence of the relationship between miniSASS and REMP data, they provide some indication that miniSASS is able to yield results similar to those derived from the REMP, particularly for rivers in a lower ecological condition (C, D and E). This, in combination with the fact that the method has been extensively assessed against SASS data and is strongly rooted in rigorous statistical evaluations, suggests that, where rigorous data collection may not be feasible due to resource constraints, miniSASS can provide defensible water quality results. Considering that many of South Africa's rivers are in a degraded state, a citizen science tool that can be used to provide evidence of a river's degraded state and draw attention to the plight of the freshwater resources, is of immense value.

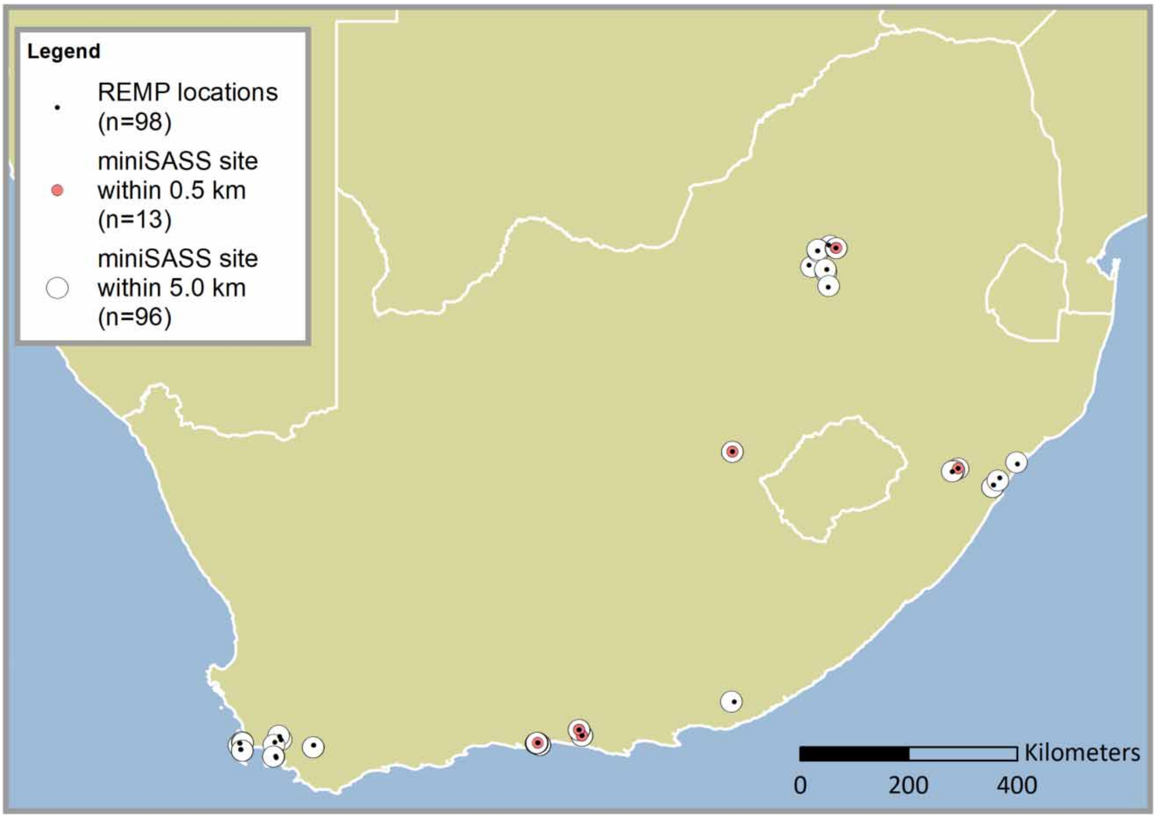

Fig. 2. | miniSASS sites in South Africa within a 500 m radius of REMP monitoring sites.

Table 2 | The frequency of samples in each ecological category recorded by miniSASS and REMP monitoring in 2017 and 2018.

Ecological category	miniSASS	REMP
A	0	0
B	0	0
C	1	7
D	5	4
E	5	0
Total	11	11

Only samples collected at miniSASS and REMP sampling points within 500 m of each other are displayed.

CONCLUSIONS

Human-created problems, that are compromising our water resources, require human-centred solutions. Simply communicating messages to people, through causal approaches, are unlikely to have any long-term, positive, effects. By involving people through co-engaged, enabling orientations such as citizen science and miniSASS, different, more inclusive and participatory, approaches become possible. This work is especially important if SDG 6 (b), stakeholder engagement, is to be realized.

The miniSASS biomonitoring technique has been successfully demonstrated in various parts of the world including India, Brazil, Canada and in various countries in eastern and southern Africa (refer www.minisass.org). Following interest in miniSASS from North America, Tembeka Dambuza developed an article (Dambuza & Taylor, 2015) with the title 'African Citizens Monitor River Health: the Stream Assessment Scoring System'. This article appeared in the USA National Water Monitoring News acwi.gov/monitoring *Sprint*, 2015 and demonstrates a widening interest in citizen science biomonitoring in other countries.

Healthy rivers generally mean healthy people and by linking research processes to indicator species such as through miniSASS, one has a useful, and accessible tool, for public participation (Graham, 2013; Taylor, *et al.*, 2013). miniSASS has much merit in engaging citizens in active and meaningful research that is real and applied and connects them to the SDGs. As a biomonitoring technique, miniSASS also has the potential for complementing the physico-chemical measurement techniques used for SDG 6.3.2. What is required, however, for greater universal applicability, is for further localizing research on the technique, in different eco-regions of the world. A more streamlined version of the miniSASS website could also be developed to help make the inputting of data more user-friendly. Furthermore, if the miniSASS technique is to be taken to scale, further resources need to be allocated to the verification and management of the data that are being placed into the website (www.minisass.org).

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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