

Reducing Pollution Through Partnership 2021/2022 Local Sense Check: The case of South Africa

Submitted to:



Submitted by:



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Contents

1.	Woi	rkshop summary	1	
2.	Woi	rkshop and country context	2	
3.	Woi	rkshop format and presentations	4	
3	.1	General organization	4	
3	.2	Format and collaboration methods	4	
3	.3	Presentations used	6	
4.	Woi	rkshop statistics	7	
4	.1	Stakeholder identification and mapping	7	
4	.2	Participant statistics	11	
5.	Fee	dback	13	
5	.1	Usefulness of the workshop for research team and participants	13	
5	.2	Main points and discussion on analysis for South Africa (Local Sense Check)	16	
	5.2.	1 Status quo of pollution impacts on species in South Africa	16	
	5.2.	2 Emerging pollution threats	21	
	5.2.	3 Pollution controls, including policy and management structures	24	
	5.2.4 Additional Factors to Consider when Assessing Pollution in South Africa 26			
	5.2.	5 Data guiding decision-making around pollution in SA	29	
	5.2.	6 Next steps for pollution research and mitigation in South Africa	31	
6.	Ref	lections and recommendations	32	
6	.1	Synthesis of workshop findings	32	
6	.2	Lessons learned and recommendations for next phase of project	35	
7.	Нур	erlinks	36	
8.	Ref	erences	36	
9.	Арр	endices	40	
9	.1	Appendix 1 – Workshop Schedule	40	
9	.2	Appendix 2 – Workshop Questionnaire	42	
9	.3	Appendix 3 – Post-workshop Questionnaire	43	
9	.4	Appendix 4 – Workshop Session A Minutes	44	
9	.5	Appendix 5 – Workshop Session B Minute	47	

List of Figures

Figure 3. Stakeholder map of key stakeholder groups in relation to pollution in South Africa. **Figure 4.** Sector representation of the attendees at the Local Sense Workshops (n = 29). 11 Figure 5. Provincial representation of participants at the South African Local Sense Pollution Figure 6. Response of participants when asked 'to what extent does the data reflect the current situation in terms of the types of flora and fauna threatened by pollution in South Africa' **Figure 7.** Provincial representation of participants responses when asked 'Which province(s) exhibit pollution hotspots and/or pollution threats to biodiversity' in the PWQ (%; n = 9; multiple Figure 8. Responses of participants when asked 'to rank pollutant categories from 1 to 6 in terms of their potential impact on biodiversity', where 6 is the highest risk, and 1 is the lowest Figure 9. Wordcloud generated from responses to question asking which pollutants require mitigation in South Africa. The size of the words in the word cloud are related to the frequency Figure 10. Emerging pollution threats to biodiversity in South Africa. The size of the words in the word cloud are related to the frequency with which they appeared in the responses from Figure 11. Response of participants when asked how much effort was being put into pollution Figure 12. Response of participants when asked what about the degree of investment being made by funders/donors in (A) pollution-related research (n = 28) and (B) pollution-related Figure 13. Additional factors to consider when assessing pollution in South Africa. The size of the words in the word cloud are related to the frequency with which they appeared in the

List of Tables

List of acronyms

CC	Climate change
CSIR	Council for Scientific and Industrial Research
DEFRA	The Department for Environment, Food and Rural Affairs
DFFE	Department of Forestry, Fisheries, and the Environment
DWS	Department of Water and Sanitation
EC	Eastern Cape
EDC	Endocrine-disrupting contaminants
EPR	Extended producer responsibility
FBIS	Freshwater Biodiversity Information System
FS	Free State
GP	Gauteng Province
INR	Institute of Natural Resources
JNCC	Joint Nature Conservation Committee
KZN	KwaZulu-Natal
NC	Northern Cape
NGO	Non-governmental organisation
PWQ	Post-workshop questionnaire
RSA	Republic of South Africa
SA	South Africa
SAAQIS	South African Air Quality Information System
SABAP	South African Bird Atlas Project
SASS	South African Scoring System
SWOT	Strengths, Weaknesses, Opportunities, and Threats Assessment
WC	Western Cape
WQ	Water quality

1. Workshop summary

Background: The effects of environmental pollution are far-reaching and impact land, soil, seas, freshwater and air and the direct and indirect threats it poses to biodiversity are of particular concern in developing countries such as South Africa (SA). This motivated a collaborative initiative among the Institute of Natural Resources (INR, South Africa), Nich Rivers-Moore (South Africa), the Joint Nature Conservation Committee (JNCC, United Kingdom) and the Department for Environment, Food & Rural Affairs (Defra, United Kingdom), which aims to reverse biodiversity loss by helping the country tackle pollution and its effects. This collaboration forms part of a broader project, viz. Reducing Pollution Through Partnership 2021/2022, which aims to scope and help design a wider pollution programme to enhance the ability of low-income countries to manage chemicals and reduce air, chemical, and waste pollution.

Methodology: To ensure an evidence-based, locally relevant approach towards achieving this aim, JNCC developed a pollution Global Scale Analysis and through the INR, facilitated two stakeholder workshops to disseminate, interrogate and develop recommendations for the improvement of the results obtained for SA (Local Scale Analysis). The workshops employed a focus group methodology and data was collected via a rapid online questionnaire administered during the workshop; open discussion to unpack/build on the responses to the poll questions; and a self-administered post-workshop questionnaire. The video and written report prepared by JNCC for sharing the Local Analysis formed the basis of all engagements with stakeholders, who were purposively selected based on a literature review and expert opinions.

Reach: A total of 29 stakeholders attended the two workshops and represented a wide variety of sectors, including all tiers of government (national, provincial and local), and the NGO, academic, and private sectors. The participants included experts in pollution research and compliance as well as a minority of stakeholders with an interest in pollution mitigation but with only basic knowledge on the topic. In terms of country reach all nine provinces were represented; it was concerning that provinces subject to high levels of pollution from mining activities (viz. North West and Mpumalanga) were poorly represented but it was encouraging to note that provinces with high levels of biodiversity (e.g. KwaZulu-Natal) were represented.

Findings: Participants were highly appreciative of being given access to the results of the analysis and being invited to participate in the workshop. The majority of the participants (68%) agreed that the results were a realistic reflection of the proportion of species threatened by pollution in SA, while 32% disagreed with this. Participants highlighted that the analysis did not always accurately reflect flora and fauna threatened by pollution in SA and key taxonomic groups could have been overlooked. More specifically, participants called for the inclusion of a number of important freshwater species, cryptic species such as diatoms, and invertebrate species and in some cases identified sources for the data on these species. KwaZulu-Natal and Gauteng were identified as pollution hotspots but the lack of recognition of other provinces as pollution hotspots may simply be an artefact of the geography of participants.

Pollutants within the Industrial and Military Effluents, and Domestic and Urban Wastewater categories were thought to pose the greatest risk to biodiversity in SA, while Excess Energy was seen to be the lowest risk. Participants identified four major categories of pollutants that need to be mitigated, namely: Acid mine drainage (AMD); Air pollution; Agricultural pollution; and Pollutants from wastewater treatment works. In terms of emerging pollutants, four major threat categories were identified by participants: Thermal; Microplastics; Traffic pollution; Pharmaceuticals and endocrine disrupting compounds. More than half of the participants indicated that moderate effort is being put into pollution mitigation and characterisation in SA, while 17% stated that very little effort is being put into these areas. Where efforts are being made in this regard, they seem to focus on domestic and industrial waste, air pollution and light pollution.

Other factors identified by the participants that should be considered when assessing pollution effects included political factors, waste management, socio-economic factors, biological pollution (e.g. invasive species) and climatic factors. While a number of potential data sources were identified by participants to improve the analysis, intermittent monitoring and data gaps were identified as challenges. Participants identified national governmental departments, namely Department of Fisheries, Forestry and the Environment and Department of Water and Sanitation as the responsible entities for pollution management in SA. Many of the participant contributions alluded to the use of other datasets that exist for the country and the inclusion of specific taxonomic groups.

Conclusions: The project and more importantly the Global Analysis was viewed as having value and was considered an urgent initiative. However, there is a need to supplement the data used for the local analysis using existing databases and future research focused on established pollutants that pose a major threat (e.g. Industrial and Military and Domestic and Urban Wastewater categories), emerging pollutants (e.g. endocrine disruptors and light pollution) and taxa (e.g. plants) that are under-represented in the IUCN database. This project presents an opportunity to encourage a country-wide approach to mitigating pollution impacts, possibly through a National Pollution Mitigation Strategy (and embedded awareness campaign) and capacity building initiatives around pollution mitigation, particularly at the community level.

2. Workshop and country context

Ambient air, chemical and soil pollution are all increasing globally, and particularly in megadiverse countries such as South Africa (SA). The risks posed by pollution to the natural environment, in terms of biodiversity and ecological infrastructure, have been widely documented in the country and include pollution from mining activities (Adhikari *et al.*, 2021), energy, economic development and (Sarkodie and Adam, 2018). The impacts being reported for freshwater habitats are of particular concern (Rimayi *et al.*, 2016), given the integrative nature of rivers. Leaders, researchers and practitioners from the fields of pollution management, environmental health and sustainable development across the country and region (Katoto *et al.*, 2019) are calling for increased research into and dialogue on pollution to elucidate the full health, environmental and economic costs of pollution. However, there are serious challenges around identifying and characterizing emerging pollutants (Nyika *et al.*, 2021) and numerous areas of data deficiency.

To comply with international agreements, the United Kingdom (UK) is scoping and designing a programme to enhance the ability of low and middle-income countries to manage chemicals and to reduce air, chemical, and waste pollution. The ultimate aim is to reverse biodiversity loss, build ecological resilience in the face of climate change and improve human health. The Department for Environment, Food & Rural Affairs (UK-Defra) is working with the Joint Nature Conservation Committee (JNCC) and SA partners, namely the Institute of Natural Resources NPC (INR) and Dr Nicholas Rivers-Moore, in implementing the Reducing Pollution Through Partnership project which aims to support the development of the wider programme. In this regard, the SA partners are undertaking the following tasks for JNCC:

- Local sense checks of the pollution global analysis developed by JNCC for SA through stakeholder consultation and engagement via workshops and/or interviews;
- Developing an evidence project with a review of publications on pollution for SA.

To develop the evidence project, data will be required from different stakeholders to validate the results of the local sense analysis, identify available datasets, monitoring and mitigation activities and any other elements the stakeholders feel should be considered for developing the wider programme. More generally the engagement with stakeholders interested in and impacted by pollution is to gather perspectives on pollution, in terms of its impacts and mitigation, and establish whether there is interest (and from which stakeholders) in co-developing elements of the programme.

JNCC developed a pollution global-scale analysis and as part of the local sense check the SA partners conducted two identically structured online workshops with stakeholders on the 10th of December 2021, where the results obtained for SA were presented and discussed. Before finalizing the methodology to be used at these workshops, the SA partners held an inception meeting with JNCC to discuss the methods that will be employed across the four work packages (A-D as listed in Section 3 of Project Proposal). To inform the design of the methodological approach the research team reviewed the Terms of Reference and the OECD's Recommendation of the Council on Integrated Pollution Prevention and Control (OECD/LEGAL/0256). The SA partners also prepared a preliminary stakeholder database for the study via a desktop analysis and an initial stakeholder consultation exercise. Described below are the details of the methods (including data collection instruments) and an initial analysis and discussion of the data collected via the two workshops. As explained in the project proposal, these data will be supplemented with other sources of data to generate the final review. More specifically, the workshops represent part of a mixed-method research approach which is based on a research toolkit (Table 1) to capture the variety of data (qualitative and quantitative) that exists for SA on the topic.

Approach	Data collection and analysis
Desktop review	Systematic literature and policy review
Quantitative	Meta-analysis of secondary data
Qualitative	 Rapid questionnaire administered during the online workshop via live polls A post-workshop questionnaire

Table 1.	Research	toolkit to be	used for	the data	collection	phase of	f the project
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3. Workshop format and presentations

3.1 General organization

Identification of appropriate stakeholders for the local sense workshop was key to ensuring that the exploration of the data and results from the Global Analysis and Local Analysis developed by the JNCC is robust. To identify the appropriate stakeholders the research team (SA partners) developed a preliminary stakeholder database using literature, policies, programmes, plans and strategies and consultation with experts from the Department of Environmental Affairs, Department of Forestry, Fisheries and Environment, the Water Research Commission and universities. The INR's extensive stakeholder database for the environmental sector (>1000 individual/organizations) was also drawn upon for this purpose.

This database was thereafter supplemented and refined based on additions and suggested exclusions provided by the Project Management Team (PMT; SA partners and the JNCC). These stakeholder groups were then used to conduct a stakeholder mapping exercise which included establishing their interest in and influence on pollution, climate change and/or biodiversity conservation. Thereafter, this was used to identify the target participants for the online workshops. An electronic invitation was sent to all target stakeholders giving them the option of attending one of the two events; this communication included a brief description of the project and three questions for the stakeholder to answer in preparation for the workshops:

- Are you presently involved in the environmental sector or decision-making that influences the sector?
- Which stakeholder sector do you belong to (e.g. private sector, public sector, donors/ funders/programmes, training and educational services, media)?
- Which province does your service/work influence (e.g. Eastern Cape, Free State, Gauteng, KwaZulu-Natal (KZN), Limpopo, Mpumalanga, Northern Cape, North West, Western Cape or National)?

Based on the responses received, specific timeslots were allocated to participants and links to the two virtual workshops were sent out. The responses to the stakeholder screening questions were also used to identify sectors, regions and stakeholder groups in the stakeholder database that required supplementation.

3.2 Format and collaboration methods

In an attempt to mitigate the risks posed by the COVID-19 pandemic, the two-hour long workshops were conducted virtually, which allowed for stakeholders to participate from around the country without needing to travel, saving time and resources. The results of the Global and Local Analysis, and the pool of questions provided by JNCC as part of the Information Package, were used to design the data collection instruments, viz. a workshop and post-workshop questionnaire, and the activity schedule for the workshop. A dry-run with the research team served to pilot the instruments, activities and online data collection tools

to be used for the workshops. After implementing changes to the schedule of activities and instruments suggested by the PMT, these were used to engage stakeholders at the workshops in the following activities with active facilitation:

- a rapid online questionnaire administered with live data capturing using the real-time Polly App ¹on MS Teams;
- open discussion to unpack/build on the responses to the poll questions;
- a self-administered post-workshop questionnaire using Google Forms ²that was emailed to the participants at the end of the workshop together with the video and written report prepared by JNCC for the Local Analysis.

A focus group methodology was used for the workshops. The number of participants targetted was higher than that suggested for classical focus group techniques, which were developed for in-person engagements, but the facilitators saw value in using a focus group approach. The approach was, however, adapted for use in online engagements which are far more challenging in terms of facilitation and data collection; the approach proved effective. The questionnaire (see Appendix 2 – Workshop Question) and schedule of activities used to trigger open discussion (see Appendix 1 – Workshop Schedule) were designed around the following themes:

- Status quo of pollution impacts of species in SA;
- Emerging pollution threats;
- Pollution controls, including policy and management structures;
- Additional factors to consider when assessing pollution in SA;
- Data guiding decision-making around pollution in SA;
- Next Steps for pollution research and mitigation in SA.

Two workshops were held on the same day, to make the workshops more manageable from a technical perspective and to accommodate more participants. Each workshop was 2 hours in duration and participants were required to attend only one event. The workshops were hosted on the MS Teams platform and allowed participants to respond to the rapid survey using the platforms described above.

Following on from the workshop, as a means of deepening quantitative feedback on pollution and species projects, the Global Analysis and data sources, a post-workshop questionnaire (Appendix 1 – Workshop Schedule; Appendix 2 – Workshop Question) was sent to the participants after the workshop. This allowed workshop participants more time to consider their responses and probe aspects that could not be addressed in sufficient detail in the workshop. The post-workshop questionnaire was accompanied by **Document E: Pilot Country Pollution Analysis Report**, and **Document D: Local sense check pilot country South Africa video** when it was sent out to participants.

¹ Polly is an innovative live polling application purpose-built for MS Teams and Slack to facilitate virtual engagements such as team meetings and surveys. Polly was utilized to present pop-up polls of the survey questions to enhance the interactive experience of participants and promote active engagement.

² Google Forms is an online-based survey platform that allows participants to click on a link to access and respond to pre-created surveys;

While not a part of this report, it should be mentioned that a combination of facilitator observations and snowball sampling ³ was used to identify a minimum of five key informants for interviews. The informants are representatives of critical sectors and/or pollution category specialists. They will be invited to participate in semi-structured interviews. The interviews will allow for further interrogation of specific pollution impacts and how these relate to species hotspots. These interviews will mainly focus on areas of uncertainty around pollution/species hotspots and information gaps identified in the stakeholder workshops and aspects of the Global Analysis that could not be probed in the workshops. The results of these interviews will feed into the Final Report.

3.3 **Presentations used**

The workshop attendees were provided with two presentations, namely a Welcome Presentation, and an Introductory Presentation (**Error! Reference source not found.** and Figure 2). The Welcome Presentation also provided attendees with definitions of terms that would be used during the workshop (Figure 2). This was to assist the participants in understanding the results of the analysis.



Figure 1. JNCC Pollution Workshop Welcome Presentation.

The Introductory Presentation was then used by the facilitator to provide the context for the workshop and to make the attendees aware of the data protection measures put in place for the workshop; once no objections were received, the meeting was recorded. The presentation was also used to introduce the hosts (JNCC and INR) and the purpose of the workshop. The facilitator highlighted that participants would be able to engage in the workshop anonymously.

³ Snowball sampling is a nonprobability sampling technique where existing study subjects recruit future subjects from among their acquaintances. Thus the sample group is said to grow like a rolling snowball



Figure 2. JNCC Pollution Workshop Introductory Presentation.

The video for the Local Sense workshop, prepared by the JNCC, was used to present the results of the Local Analysis.

4. Workshop statistics

4.1 Stakeholder identification and mapping

The stakeholder database was generated via the systematic literature review and expert consultation was used as the input data for the stakeholder mapping exercise. This included experts from the University of KwaZulu-Natal (UKZN), Durban University of Technology (DUT), Department of Fisheries, Forestry and the Environment (DFFE), and members of the environmental sector, and served to identify seven major stakeholder groups, each consisting 3-7 categories (see Figure 3).





The stakeholder map was expanded on by identifying institutions/organizations/departments associated with each of these categories based on the inputs from participants at the workshop, the questionnaires and the literature (Table 2).

Table 2. Categorisation of important stakeholder entities for pollution in South Africa.

Public/Government	Private	Academia	Civil Society/NGO	Media	Funders & Donors
Agriculture, Land Reform and Rural Development (DARLLD)	Sapro International Pty Ltd	University of the Witwatersrand	International Union for Conservation of Nature	News24	Water Research Commission (WRC)
Communications and Digital Technologies (DCDT)	GIBB Engineering and Architecture	University of Western Cape	SaveAct	Mail & Guardian	International Crane Foundation
Cooperative Governance and Traditional Affairs (COGTA)	Wildlands Conservation Trust	Nelson Mandela University	GenderCC Southern Africa	Sowetan Live	Global Environment Facility (GEF)
Ezemvelo KZN Wildlife (EKZNW)	The Biodiversity Company	University of KwaZulu-Natal	Birdlife South Africa	The Citizen	The Lewis Foundation
Forestry and Fisheries and Environment (DFFE)	Exigent Environmental & Engineering	University of Cape Town	AMA Travel and Tours trading as AMA Marketing	Daily Maverick	
Higher Education, Science and Technology (DHET)	GM Richards Bay Minerals	Durban University of Technology	Fountainhill Estate	The South African	
International Relations and Cooperation (DIRCO)	Biodiversity Initiative, Forest Trends Association & independent consultant	North-West University	Professional Hunters' Association of South Africa (PHASA)		
Mineral Resources and Energy (DMRE)	PlasticsSA	Rhodes University	Wetlands International -Africa		

9 | P a g e

National Treasury (NT)	Eco-Pulse Environmental Consulting Services	Walter Sisulu University	Wildlands	
Planning Monitoring and Evaluation (DPME)	Ecolmvelo	Cape Peninsula University of Technology (CPUT)	Duzi-uMgeni Conservation Trust	
SANParks	Conservation South Africa	Stellenbosch University	Institute of Natural Resources	
South African National Biodiversity Institute (SANBI)	SpillTech	Central University of Technology	Environmental Monitoring Group	
South African National Parks (SANParks)	Drizit Environmental	University of Johannesburg	Center for Environmental Rights	
StatsSA		University of Pretoria	Wildlife and Environment Society of South Africa	
Trade, Industry and Competition (DTIC)		University of Zululand		
Transport (DOT)				
Water and Sanitation (DWS)				

4.2 Participant statistics

A total of 29 stakeholders attended the two Local Sense workshops on the 10th of December 2021. The participants represented a wide variety of sectors, including all levels of government (national, provincial and local), and the NGO, academic, and private sectors (Figure 4). Dominance of the Public/Government sector was evident. All the workshop participants completed the workshop questionnaire which was administered during the workshop.





In the post-workshop questionnaire (PWQ), a sub-sample of the workshop participants (n = 9) provided information on their level of expertise in/knowledge on pollution. Participants were encouraged to provide examples of their involvement in pollution management and whether they have a general or specific area of knowledge of pollution. Importantly, some participants indicated that they had good-to-high levels of knowledge on pollution in SA, with several indicating (as evidenced by the comments below) that they had completed (or were in the process of completing) tertiary studies and/or were involved in academic/applied research on pollution in SA.

It was useful to note that some of the participants were involved in compliance around pollution and were working with both industry and the public sector on matters related to this. However, there were also participants with basic to average levels of knowledge on pollution.

- "My PhD study was focused on potentially toxic element pollution (chromium specifically) in mining/smelting region if Sekhukhuneland in Limpopo"

- "Good (in terms of level of expertise) - ranging from field survey, evaluation of data and reports. Recently developed the Resource Quality Objectives for the Olifants and Vaal rivers for DWS. Worked by 25 years in KZN with Umgeni Water and INR"

- "I currently research and teach broad environmental impacts in higher education. My previous experience in pollution management includes all forms of industrial pollution in the textile industry, different forms of pollution managed by local government and water pollution associated with municipal wastewater treatment. My current research relates to catchment-base water pollution and risk assessment associated with this"

- "High (in terms of level of expertise). MSc focussed on contamination, 14 years consulting experience in pollution. Worked as affiliate consultant with UNEP on World Water Quality Alliance Africa use Cases assessing water quality at Lake Victoria Basin (Kenya/Tanzania/Uganda) and Volta River Basin (Ghana)"

- "I work as an environmental manager responsible for pollution management incl inspections, compliance monitoring and enforcement"

- "My PhD study was focused on potentially toxic element pollution (chromium specifically) in mining/smelting region of Sekhukhuneland in Limpopo"

- "Average (in terms of level of expertise) - general desire to combat or reduce pollution of agricultural pollutants as well as the impact of solid waste, sewage etc. on primary resources such as water and land"

- "I have a basic knowledge and involved in community initiatives and

Participants were asked to identify province(s) within SA for which they had a good understanding of pollution and its impacts on biodiversity. Participants were allowed to select more than one province, where necessary. There was a definite bias in terms of representation from KZN and to a lesser extent Gauteng. Provinces such Free State and North West were clearly poorly represented (Figure 5). This is concerning since provinces such as North West and Mpumalanga are subject to high levels of pollution from mining activities. In contrast, it was encouraging to note that provinces that have high levels of biodiversity such as KZN, Western Cape and Eastern Cape were represented.



Figure 5. Provincial representation of participants at the South African Local Sense Pollution Workshops (%; n = 29; multiple responses permitted).

As mentioned in the Methods section workshop participants were given the opportunity to respond to the structured questionnaire via the Polly App on Microsoft Teams or Google Forms. The vast majority of the participants chose to answer the questions using the Polly App (22) rather than the Google Forms (7) and irrespective of the platform used, there were very few cases of 'no answer provided'. As mentioned above, a sub-sample (n = 9) of the workshop participants completed the post-workshop questionnaire which was administered using Google Forms and distributed via email after the completion of the workshop.

5. Feedback

5.1 Usefulness of the workshop for research team and participants

The participants were highly appreciative of being given access to the results of the analysis and being invited to participate in the workshop. The tone of and level of participation (see workshop minutes in Appendix 4 – Workshop Session A Minutes and Appendix 5 – Workshop Session B Minute) at both workshops provide evidence that participants engaged with the data described in the presentation video and were willing to comment on the value and shortcomings of the analysis.

One of the primary purposes of the workshop, apart from gauging the value of and identifying ways of adding to the analysis, was one of awareness-raising around the threats posed to biodiversity by pollution and to encourage local government, scientific and civil

society engagement on the socio-ecological linkages among pollution, biodiversity and climate change. In this regard, as part of the post-workshop questionnaire, attendees were asked whether they thought the results were a realistic reflection of the proportion of species threatened by pollution in SA. The majority of the participants (68%) agreed that the results were a realistic reflection of the proportion of species threatened by pollution in SA, while 32% disagreed with this (n = 28). Importantly, 8/29 participants highlighted (see comments below) the importance of the study and recognised that it is a great starting point, but is likely to be missing many species as evidenced by their comments below.

- "The results are an excellent starting point, and generate discussions. However, I think the IUCN-category species are probably only the 'tip of the iceberg.'"

- "Yes - at a high level, but of course more interrogation of data at a finer scale."

- "It is useful, but poorly enforced."

- "It only focusses on the rare and threatened species, what about the more common species that are affected but dont show the impacts as they are generalists?"

- "Plant species do not seem to be adequately represented. The results may be biased in terms of the available information and published literature. What about grey literature."

Furthermore, participants were asked to indicate the extent to which the data reflects the current situation in terms of the types of flora and fauna threatened by pollution in SA (Figure 6). The majority (59%) of the respondents indicated that the data was moderately reflective of the current situation while 34% indicated that the data was largely (to very largely) reflective of the situation in the country. It was encouraging to note that just 7% of participants thought the results to reflect the current situation very little.



■ Very little ■ Little ■ Moderate ■ Large ■ Very large

Figure 6. Response of participants when asked 'to what extent does the data reflect the current situation in terms of the types of flora and fauna threatened by pollution in South Africa' (n = 29).

However, comments by participants that the analysis did not always accurately reflect flora and fauna threatened by pollution in SA should not be ignored (see below) since they allude to the possibility that key taxonomic groups could have been overlooked/given more attention. More specifically, participants called for the inclusion of a number of important freshwater species, cryptic taxonomic groups such as diatoms, and invertebrate species.

- "There's a range of other important species that probably wouldn't have been included in the analysis that would be good indicators, but cryptic, such as diatoms, algae species etc. Also, the secondary effects (both positive and negative for opportunism as mention in the discussion session)."

- "It seems quite limited, possibly due to lack of Biodiversity Data in many parts of the country."

- "The IUCN threatened spp. list only includes limited invertebrate species. Given globally 1 in 5 invertebrates are threatened, this suggests that they are mis / under-represented. This limitation should be clearly noted."

5.2 Main points and discussion on analysis for South Africa (Local Sense Check)

Themes were used to define the scope of the project and by implication the foci of the workshops. These themes were identified by the research team during the planning phase of the workshops, in collaboration with JNCC, based on the literature and the Workshop Information Package provided by the JNCC (including the Pilot Country Pollution Analysis Report, the Local sense check pilot country SA video, and the Local Sense Questions Pool). The themes were used to design the questions posed to the participants during the workshops and in the post-workshop questionnaire. Later, some of the themes were adapted/modified slightly to accommodate the data that emerged from the workshops. The data collected during the workshops and after via the post-workshop questionnaire are presented and discussed in relation to these themes in this section.

5.2.1 Status quo of pollution impacts on species in South Africa

The questions posed as part of this theme were designed to gain an overview of pollution in SA, location of pollution hotspots, and how these impacts on biodiversity. Insights into pollution hotspots gained from workshop attendees can hopefully be compared with the results of the IUCN pollution analysis, which can be important when determining the way forward in terms of mitigating pollution to protect biodiversity. During the course of the workshops and in the PWQ, participants were asked which three questions relating to the status quo of pollution in SA, namely:

- 1. Which provinces exhibit pollution hotspots and/or pollution threats to biodiversity?;
- 2. Which pollutant threats do you think pose the greatest threat to species?; and
- 3. Which pollutants need to be mitigated in SA?

When asked which SA provinces exhibit pollution hotspots and/or pollution threats to biodiversity, most participants answered KwaZulu-Natal and Gauteng (77.8% and 66.7%; Figure 7) while zero participants answered Northern Cape. However, there is a strong correlation between provinces exhibiting pollution hotspots and provincial representation (Figure 5 and Figure 7), where KwaZulu-Natal and Gauteng were the best represented provinces, followed by Western Cape.



Figure 7. Provincial representation of participants responses when asked 'Which province(s) exhibit pollution hotspots and/or pollution threats to biodiversity' in the PWQ (%; n = 9; multiple responses permitted).

Participants were asked to rank pollutant six major pollutant categories (viz. Agricultural and Forestry Effluents, Industrial and Military Effluents, Domestic and Urban Wastewater, Garbage and Solid Waste, Air-borne Pollutants, and Excess Energy) in terms of their potential impact on biodiversity. Based on responses from the participants, Industrial and Military Effluents, and Domestic and Urban Wastewater posed the greatest risk to biodiversity in SA while Excess Energy was seen to be the lowest risk (Figure 8). However, it should be noted that the Agricultural and Forestry Effluents, Garbage and Solid Waste and Air-borne Pollutants categories were also awarded average scores >4 and hence, represent significant threats.



Figure 8. Responses of participants when asked 'to rank pollutant categories from 1 to 6 in terms of their potential impact on biodiversity', where 6 is the highest risk, and 1 is the lowest risk (PWQ; n = 9).

Participants in the workshop were asked which pollutants needed to be mitigated in SA, four major categories of pollutants emerged when the data were analysed (Figure 9), namely:

- Acid mine drainage (AMD);
- Air pollution;
- Agricultural pollution;
- Pollutants from wastewater treatment works (WWTW).



Figure 9. Wordcloud generated from responses to question asking which pollutants require mitigation in South Africa. The size of the words in the word cloud are related to the frequency with which they appeared in the responses from participants.

- Acid mine drainage (AMD)

Mine drainage is known to result in several problems, including contaminated drinking water, disrupted growth and reproduction of aquatic plants and animals, and the corroding effects of acids on parts of infrastructure such as bridges (Akcil and Koldas, 2006). Acid mine drainage is also known to cause elevated levels of metals and sulfates and alter pH levels in aquatic ecosystems. Additionally, AMD is known to affect streams heavily, resulting in highly stressed ecosystems (Hogsden and Harding, 2012). Streams affected by AMD typically have low pH, high concentrations of dissolved metals, resulting in an unsuitable environment for aquatic biota (Hogsden and Harding, 2012). AMD is prominent in parts of SA, particularly around the gold mines in Gauteng and the coal mines in Mpumalanga (Ochieng *et al.*, 2010; McCarthy 2011).

- Air pollution

Air pollution is of particular concern around KZN, Gauteng and Mpumalanga, where air pollution is driven by industry and power generation (Holland, 2017; Appalasamy *et al.,* 2018). Holland (2017) found that air pollution from coal-fired power stations in SA kills approximately 2,200 people each year. While air pollution is most often studied in relation to

its adverse impacts on human health, the impacts of air pollution on biodiversity are often overlooked and understudied (Lovett *et al.*, 2009). However, there are several ways in which poor air quality impacts on the environment, such as the acidification and eutrophication of lakes and rivers, bioaccumulation of heavy metals such as mercury in aquatic food webs, and nitrogen deposition on plants (Lovett *et al.*, 2009 and De Schrijver *et al.* 2011). There have been a few efforts in SA to look at the effects of air pollution on trees (Areington *et al.*, 2017; Appalasamy *et al.*, 2018) but reports on the direct effect of air pollution on the survivability of other taxonomic groups are limited. The transboundary nature of air pollution points to the need for inter- municipal/provincial and country collaboration in mitigating air pollution. The same can be said for pollution of fresh water bodies.

- Agricultural pollution

The impacts of pollutants arising from various types of agriculture are widespread and relatively well studied in many parts of the world. Intensification of agricultural production in some regions poses a major threat to the ecology of agro-ecosystems impairing the state of soil, water and air and reducing biological diversity (Stoate *et al.*, 2009). Agriculture destroys biodiversity by converting natural habitats to intensely managed systems and by releasing pollutants, such as greenhouses gases, pesticides and nutrients (including nitrates and phosphates) (Dudley and Alexander, 2017). In this regard, agriculturally driven land-cover change and habitat loss have seen large reductions in biodiversity in parts of SA. Jewitt *et al.*, (2015) found that the province of KZN saw a 1.2% reduction in natural land-cover, each year since 1994. Food value chains further amplify impacts on biodiversity through energy use, transport and waste (Dudley and Alexander, 2017). Suggestions to mitigate the impacts of agricultural pollutants from workshop attendees included the use of locally grown food and improving monitoring.

- Pollutants from WWTW

Underfunctioning wastewater treatment works (WWTW) are increasingly becoming the norm in SA and with large portions of the rural population flooding into urban areas, there is increasing stress on the infrastructure in place to handle wastewater (Cullis *et al.*, 2019). Under-treated or spilled wastewater being fed into rivers can result in elevated concentrations of nutrients and contaminants, and reduced biotic richness (Hamdhani *et al.*, 2020). Chronic exposure to nutrients and contaminants (such as *E. coli*) from WWTWs can result in aquatic population shifts, favouring tolerant species, seeing the disappearance of sensitive species (Hamdhani *et al.*, 2020). Attendees at the workshops recommended that improved compliance monitoring is required from local and national government to ensure that WWTWs are compliant when releasing treated effluent into the river. - "Acid mine drainage. Agricultural fertilizer runoff. Better understanding of largescale industrial complexes and contamination."

- "Nutrients, salts, AMD, water temperature effects, atmospheric depositions (sulpher etc), EDCs."

- "Solid waste; chemicals that are impacting on food items i.e. pesticides etc; outputs from waste water treatment works (E.coli levels and other associated pollutants)."

- "Metals, POPs, various endocrine disruptors, various chemical wastes - it has to be controlled at the source, so a proactive approach instead of reactive when it is already in the system."

5.2.2 Emerging pollution threats

A general concern from attendees at the workshop was the lack of monitoring of pollutants, and more specifically the lack of compliance monitoring to ensure the industry conforms with environmental laws and regulations. This could also point to poor tracking of emerging pollutants. This motivated a set of questions that were designed to gain an insight into the emerging pollutant threats in SA. Insights into emerging pollution threats gained from workshop attendees can be used to guide researchers when updating the JNCC pollution maps. Participants were asked if they knew of any major and/or emerging pollution threats in SA that were not included in the analysis. From the answers received, four major threat categories emerged, namely (Figure 10 and comments below):

- Thermal Pollution (associated with climate change and anthropogenic activities);
- Microplastics;
- Traffic pollution;
- Pharmaceuticals and endocrine disrupting compounds.

- "Emerging pollution threats: Micro-pollutants, EDCs and emerging contaminants (pharmaceutical etc). Also water temperatures (both discharges and resulting from climate change)."

- "Contaminants of emerging concern incl. pharmaceutical drugs and "recreational" drugs."

- "Microplastics and chemical spillages."

- "There are Endocrine disruptors that should be kept in mind when assessing impacts."

- "Traffic pollution threat."

- "Pharmaceuticals and endocrine-disruptors; new additives and chemicals that may be associated with the health and beauty industry."



Figure 10. Emerging pollution threats to biodiversity in South Africa. The size of the words in the word cloud are related to the frequency with which they appeared in the responses from participants.

- Thermal Pollution (associated with climate change and anthropogenic activities)

The impacts of thermal pollution resulting from climate change on biodiversity, caused by increased global ambient temperatures resulting in increased air, soil and water temperatures, were raised by several participants at the workshop. Importantly, thermal pollution can decrease water quality, having large effects on oxygen levels, pH levels, and the overall wellbeing of ecosystems (Verones *et al.*, 2010; Dallas and Rivers-Moore, 2014). While largely understudied in the South African context, there have been several studies examining the impacts of pollutants associated with increased temperature on biodiversity (Areington *et al.*, 2017; Appalasamy *et al.*, 2018) but research on the direct effects of thermal pollution on biodiversity within South African ecosystems is limited (but see Buhrmann *et al.*, 2016). This area of research needs to be grown within the country since proactive assessment and monitoring are seen as the key for the identification of ecological triggers and thresholds, allowing for more accurate and informed decisions (Dallas and Rivers-Moore, 2014).

- Microplastics

Microplastics were raised as an emerging pollutant on several occasions during the stakeholder workshops. Attendees expressed that they are increasingly abundant in South African ecosystems, particularly aquatic (freshwater, estuarine, and marine) ecosystems. For example, a recent study showed that microplastics were found in more than half the juvenile

fish sampled in four mangroves on the east coast of SA (Naidoo *et al.*, 2020). In terms of the impacts of microplastics on aquatic organisms, there are studies that show that microplastics can result in genotoxicity, oxidative stress, changes in behavior, reproductive impairment, mortality, and altered population growth rate (Barboza *et al.*, 2020). However, this remains mostly unstudied in the South African context and requires further investigation (Naidoo *et al.*, 2020).

- Traffic Pollution

Traffic pollution was raised as an emerging pollutant impacting on biodiversity in SA that was perhaps not included in the data analysis. Increased traffic (motor vehicles, trucks, trains, busses, etc) results in air and noise pollution (Zhang and Batterman, 2013), and microplastics (Järlskog *et al.*, 2021); all of which have been discussed individually above.

- Pharmaceuticals and endocrine disrupting compounds

Pharmaceuticals and endocrine disrupting compounds (EDCs) emerged strongly as a pollutant threat category in the workshops. Global pharmaceutical consumption is rising with the growing human population, and increased access to western medicine; SA is no different (Arnold *et al.* 2014). Many middle to low income countries, including SA, do not have regulations pertaining to pharmaceutical traces as pollutants in aquatic systems (Ngqwala and Muchesa, 2020). This absence of 'prescribed limits' has resulted in very little or no environmental monitoring of these chemical stressors (Ngqwala and Muchesa, 2020). Elsewhere in the world, studies have found pharmaceuticals in a wide range of ecosystems and organisms, including synthetic estrogen in freshwater fish populations downstream of a WWTW in Ontario, Canada, which resulted in the feminization of young male fish (Kidd *et al.*, 2007).

Across each of these themes, attendees expressed concern for the lack of pollution control and long-term monitoring, while highlighting the need for additional research to be done in these areas. Research needs to focus on how these emerging pollutants impact the fauna and flora, at an individual level and at an ecosystem level. Generating recommendations on this may require a systematic analysis of the research done on pollution in SA in the recent past. In the final report, we intend identifying these thematic areas/topics that future pollution research in the country should focus on via a bibliometric analysis.

- "Intermittent and spotty monitoring."

- "Very little government data. Mostly assessments by polluter that are not shared widely."

- "Primarily water quality data arising from the National Chemical Monitoring Program - this may be limited as not necessarily broad spectrum."

5.2.3 Pollution controls, including policy and management structures

The purpose of this theme was to gain an insight into the policies, tools and management structures in place in SA to control pollution. In-depth knowledge of pollution control measures in SA are essential for a project of this nature since its outcomes will guide future research and mitigation efforts. During the course of the workshops, participants were asked how much effort they thought was being put into pollution mitigation and characterization in SA and which entities were responsible for pollution management.

More than half of the participants (52%) indicated that moderate effort is being put into pollution mitigation and characterization in SA, while 17% stated that very little effort is being put into these areas (Figure 11). The minority (14%) indicated that large effort is being into pollution mitigation and characterization in SA.



Figure 11. Response of participants when asked how much effort was being put into pollution mitigation/characterization in SA (n = 29).

Additionally, participants were asked to identify pollutants that were being mitigated and which entities were involved in the process. It was evident that the participants found this question challenging, based on the poor response rate (14%; n = 29). Nevertheless, from the answers received three categories emerged, namely:

- Domestic and industrial waste;
- Air pollution;
- Light pollution.

- "Sewage which is discharged by municipalities during pump failures."
- "Air Pollution by Government and Private stakeholders."
- "Domestic and industrial waste users, municipalities, national departments."

- "Light pollution- impacts glowworms and nocturnal species - need to expand on this research/data."

- Light Pollution

Light pollution was raised as a concern by a participant, particularly for glow worms and nocturnal species; the participant went on to mention that additional research is required on the topic in SA. Globally, there have been numerous studies focusing on the impacts of light pollution on biodiversity, particularly nocturnal species (e.g. Longcore and Rich, 2004; Gaston *et al.*, 2013; Mu *et al.*, 2021). Artificial light threatens biodiversity by changing the night behaviour of organisms, e.g. insects getting attracted to street lights.

- Domestic and industrial waste

Management of solid waste is a major challenge in developing countries such as SA, where a lack of all-inclusive planning and management has challenged the progress towards circularizing the economy (Pariatamby *et al.*, 2019). Recognizing shortcomings of the SA government to properly handle waste, the private sector is attempting to improve in sustainable waste management. The private sector is doing this in several ways, such as formalising waste pickers, promoting recycling at all stages of the waste cycle, and promoting practices that divert wastes from landfills (Pariatamby *et al.*, 2019).

Importantly, there were a few responses relating to mitigation and characterization efforts by the workshop attendees. While this might be attributed to attendees finding the question challenging, it speaks to a possibly larger problem in SA, i.e. limited efforts around pollution mitigation and characterization. This suggestion is reinforced by the fact that when participants were asked about the degree of investment being made by funders/donors in pollution-related research and mitigation, the majority (52%) of respondents indicated that a moderate degree of investment was being made in terms of mitigation while 44% indicated that this investment was little to very little (Figure 12A). The minority (4%) indicated that there was large investment in pollution mitigation. In terms of investment by donors/funders in research on pollution, just 39% of respondents indicated a moderate degree of investment was being made by funders and donors (Figure 12B). It was interesting to note though that 22% of respondents indicated large investment in pollution-related research.

A: Pollution-related Research

B: Pollution-related Mitigation



Figure 12. Response of participants when asked what about the degree of investment being made by funders/donors in (A) pollution-related research (n = 28) and (B) pollution-related mitigation (n = 27).

5.2.4 Additional Factors to Consider when Assessing Pollution in South Africa

The purpose of this theme was to gain an insight into the best approach to take when assessing pollution in SA. In-depth knowledge of external factors, such as political, climatic, or socio-economic, can help guide future research and mitigation efforts. Participants were asked to list any other factors they thought were important to consider when assessing pollution during the workshops and via the PWQ. Answers were provided verbally or in text format. From these answers, five major themes emerged (see Figure 13 and comments below) and these are expanded on below.



Figure 13. Additional factors to consider when assessing pollution in South Africa. The size of the words in the word cloud are related to the frequency with which they appeared in the responses from participants.

- "Socio-economic challenges. Service provider challenges (waste water treatment, refuse collection/disposal, solid waste site management including leachate)."

- "Absolutely - socio-economic, climate (impact magnification under CC), political yes (hydro-diplomacy), health and well-being being another."

- "Yes, especially w(h)ere communities are in close proximity, socio-economic, political, and traditional affairs play a huge factor."

- "Social factors such as areas that do not receive basic services such as refuse removal do contribute to pollution. People tend to burn their waste and cause air pollution or dispose it in rivers which effects the aquatic environment."

- "Apart from EPR which focused only in few products, all other industry and stakeholders' roles and responsibilities are also equally important in preventing pollution and biodiversity loss. It is therefore important to assess their contribution in both pollution prevention as well as biodiversity conservation."

- Political factors

The South African political landscape can be unpredictable and volatile, with dozens of politically-motivated riots and protests taking place each year. ISS Africa have been tracking protests in SA since 2013, including location and the reason for protest. They found that there have been 2,330 protests between 2013 and 2021 in SA, an average of 291 protests

per year (ISS Africa, 2022). On many occasions, protests have resulted in significant pollution of the environment, such as the protests which resulted in a chemical spill in the Ohlanga River in 2021 (Mail & Guardian, 2022).

Furthermore, the data (Figure 13) suggests that there may be a lack of political will around/support for pollution assessment, and by association, pollution mitigation, particularly amongst local government and traditional authorities. When assessing and mitigating pollution in SA it will therefore be particularly important to consider socio-ecological systems that fall under the rule of traditional authorities. Dealing with traditional authorities can present unique challenges and opportunities.

- Waste Management

The lack of service delivery was brought up by attendees as a major factor to consider when assessing pollution in SA, particularly in rural areas and lower income communities. This has already been discussed above but it is worth stress that a lack of service delivery, such as proper waste and sewage disposal, results in increased pollution entering rivers and oceans. This is exacerbated by the country's reliance on a linear as opposed to circular economy. Many households have no choice but to burn or illegally dump their solid waste, such as plastic, rubber and metal, as municipal refuse collection does not reach their area.

One participant discussed the roles and responsibilities of industry in waste management, stating that extended producer responsibility (EPR) only extends to a few products. The participant outlined that it is important to assess industry's contribution to pollution and biodiversity, and how industry can assist in preventing pollution and biodiversity loss.

- Socio-economic factors

Socio-economic impacts of pollution are varied and plentiful; for example, Green Peace (2018) estimated in 2018 that air pollution resulted in 14,000 preterm births per year in SA, and 13,000 premature deaths. Poor water quality is also detrimental to human health. For instance, immune suppression, acute poisoning and reproductive failure are some of the illnesses induced by toxins in industrial waste water (Haseena *et al.*, 2017). Infectious diseases such as typhoid (Juneja and Chauhdary 2013) fever, diarrhoea, cholera, skin and kidney problems are also spread through polluted water (Khan 2011). Poverty and poor governance can lead to increased exposure to these risks.

When participants were asked to what degree reducing pollution could affect the South African economy and livelihoods in the country, the majority of the participants stated that the South African economy (66.7%; negative effect) and livelihoods (77.8%; positive effect) could be affected 'a lot', while the remaining participants all stated that the economy (33.3%; negative effect) and livelihoods (22.2%; positive effect) could be affected somewhat by reducing pollution (PWQ; n = 9).

- Biological pollution

Biological pollution can include invasive plants (and their propagules) and animals that can compromise ecosystem health and functionality (Horan *et al.,* 2002; Elliot, 2003; Messing and Wright, 2006). These non-native invasive species can be released into new

environments through polluting events such as release of ballast water from shipping vessels or transfer from imported materials. Whether they come from distant habitats or are introduced through biotechnology applications, invasive species have the potential to out-compete native species and reduce biodiversity (Elliot, 2003); they represent the second most common cause of recent species extinction globally (Bellard *et al.*, 2016). One participant noted that the JNCC's pollution hotspot analysis did not include data on biological invasions in the assessment; this was based on the way in which the IUCN categorises pollution and biological invasions. Both named and unnamed biological invasions are placed into a separate threat category to pollution (See IUCN Threat Categories v 3.2). However, there is a growing body of literature that calls for invasive species to be recognised as pollutants (Horan *et al.*, 2002; Elliot, 2003; Messing and Wright, 2006). Biological invasions should, therefore, be considered in the future pollution hotspot analysis.

- Climatic factors

Several participants raised climatic conditions as an important factor when assessing impacts of pollution on biodiversity that should be taken into consideration. There are multiple climatic conditions that could result in increased pollution or increased impacts of pollution. For example, heat waves can negatively impact air quality by increasing ozone pollution which has been shown to negatively impact on human health (Filleul *et al.*, 2003), however, there was limited information to show the impact of ozone pollution on biodiversity. As another example, increased river water temperature results in increased release rates of sediment-bound metals, such as Zinc, Lead, and Copper (Li *et al.*, 2013).

Participants were asked if the interaction between pollution and climate change reflected for SA in terms of threat to species was a realistic representation during the PWQ (n = 9). The majority (n = 6) of participants responded by saying that the interaction between pollution and climate change reflected for SA in terms of threat to species was a realistic representation. The three people who stated that the interaction was not a realistic representation were asked to explain their answers. The participants noted here that the relationship between climatic conditions in general, climate change in particular, and pollution were too complex and location-specific to be evaluated (see comment below as an example).

- "Climate change and pollution are completely different things and cannot be evaluated on the same scale. It is simplistic to relate CC to biodiversity without going into detail at a local level - on what the mode of change due to CC is. Some rivers may end up with more water others with less, etc."

5.2.5 Data guiding decision-making around pollution in SA

The purpose of the questions in this theme was to gain an insight into the data that is being used to guide decision-making around pollution in SA. Responses from participants can be used to find data gaps and to improve pollution-related decision-making and research. During the course of the workshops, participants were asked what types/sources of data

presently guiding decision-making around pollution in SA. Answers were received verbally and in text format. From the participant's answers, two major themes emerged, namely:

- Available data
- Intermittent monitoring and data gaps

- "Very little government data. Mostly assessments by polluter that are not shared widely."

- "Primarily WQ data arising from the national chemical monitoring program - this may be limited as not necessarily broad spectrum."

- "We have an environmental health unit that has specific units dealing with waste and air quality..."

- "Environmental Impact Assessments, Monitoring instruments such as Ambient Air Quality Monitoring Station etc..."

- "Intermittent and spotty monitoring."

Available data

A number of very valuable pollution and biodiversity databases were suggested by attendees during the course of the workshop and these are listed in Table 3. While there were strong recommendations to draw on these databases, there was limited input from participants on how to bring these different sources and types of data together into one systematic analysis of the effects of pollution on biodiversity. One recommendation from the participants was that these databases be used to possibly bring 'at risk' taxa into the analysis but there was little clarity on whether the quality of the data and the criteria applied for inclusion were in agreement with those used for the IUCN database.

Table 3. Pollution and biodiversity databases and data sources recommended by workshop attendees for decision-making.

Туре	Database
Air Quality	South African Air Quality Information System
Ecological	miniSASS
Ecological	Freshwater Biodiversity Information System
Ecological	Virtual Museum
Ecological	Southern African Bird Atlas Project 2
Ecological	Coordinated Waterbird Counts
Various	Specialist reports and academic papers
Waste	South African Waste Information Centre
Waste	CSIR Pollution tracking

- Intermittent monitoring and data gaps (see comments above)

Several participants reported that monitoring was intermittent and that databases had several large gaps. For example, the Department of Water and Sanitation (DWS) has had to cut water quality monitoring sites across the country in the past due to budgetary cuts. For the same reason, DWS ceased with their nationwide river health monitoring programme, which provided critical information on the wellbeing and state of key rivers and water resources. Long-term and routine monitoring of pollution and biota enables better-informed decisions which improve conservation and reduce mitigation costs.

5.2.6 Next steps for pollution research and mitigation in South Africa

Pollution mapping in SA, at a scale that can be useful for planning and mitigation, was openly discussed during stakeholder workshops and in the PWQ. There was widespread agreement that more work needs to be done on pollution research and mitigation in SA (Figure 12) and participants raised several interesting points when asked what information should be made available to decision-makers to mitigate pollution. Suggestions included life cycle analyses of key pollutants and their impacts, real-time monitoring of key pollutants and resources, and the long term effects of accumulation of pollutants.

- "Life Cycle Analyses of key pollutants in the environment and its impact."
- "Long term effects of accumulation, possible environmental change as a result of climate change and pollution combined."
- "Better real-time monitoring. Priority water pollution hotspot maps."

Participants were asked to list up to three entities who were responsible for pollution management in SA. The majority of participants listed national governmental departments, namely Department of Fisheries, Forestry and the Environment (77.8%), and Department of Water and Sanitation (55.6%) as the responsible entities for pollution management in SA.

 Table 4. Response of participants when asked 'Which entities were responsible for pollution management in South Africa' (n = 9; up to three answers per participant were permitted).

 Responsible Entity
 Number of

Responsible Entity	Responses
All levels of Government	22.2%
Department of Forestry, Fisheries and the Environment	77.8%
Department of Mineral Resources	33.3%
Department of Health	11.1%
Department of Water and Sanitation	55.6%
Industry	11.1%

Local Government	11.1%
NGOs	44.4%
State Owned Enterprises	22.2%

The comments received in the PWQ (see comments below) supported the concerns expressed during the workshops around the extent to which the results reflect the current situation in the country (see Status quo of pollution impacts on species in South Africa) and were particularly useful in identifying areas/ways in which the analysis could be improved going forward, i.e. made to be a more a realistic reflection of the proportion of species threatened by pollution in SA. Importantly, many of these comments alluded to the use of other datasets that exist for the country and the inclusion of specific taxonomic groups that may be under-represented in the IUCN database used for the present analysis. Some potential databases recommended by participants have been listed in Table 4.

- "But should also include hot spots in highly industrialised and overpopulated areas as high pollution emanate from such areas, e.g. Gauteng and KZN."

- "I do not accept the IUCN Red list as an adequate representation of biodiversity or the threat to it. Importantly aquatic ecosystems were only recently included and are still poorly reflected. Also, there is a philosophical issue here - pollution is most detrimental to ecosystems as a whole, threatened red list species are not necessarily even sensitive to pollution."

- "I believe the threat level extends beyond the pollution hot zones and that pollution is spread more widely through climatic and population movements."

- "It only focusses on the rare and threatened species, what about the more common species that are affected but don't show the impacts as they are generalists?"

- "Plant species do not seem to be adequately represented. The results may be biased in terms of the available information and published literature. What about grey literature?"

6. **Reflections and recommendations**

6.1 Synthesis of workshop findings

The findings (data) gathered during the workshops were synthesized by conducting a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis of the Global and Country Analysis. Table 5 details a combination of the comments from the workshop participants and inputs from the facilitators, classified by SWOT category. The "Opportunities" represent pathways for addressing the "Weaknesses", while the "Threats" represent the wider country-specific landscape that has the potential to erode future pollution mitigation projects targeting identified species conservation measures.

Table 5. SWOT	analysis of the	Global and Cour	ntry Analysis.
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STRENGTHS	WEAKNESSES
 Oseful high-level approach for identifying specific pollution threats and geographical focal areas (i.e. hotspots for pollution impacts on species). Pollutant categories appear to be extensive and reflective of the pollution profile of South Africa. Hierarchical classification of pollution categories is useful for the linked meta-analysis component. Heatmaps are useful as an approach readily understood by the public (<i>This representation has become more familiar since early 2020 with COVID hotspots reported in the media</i>). The use of restricted-range species is a practical way for targeting specific areas for further focus. Highlighting taxonomic groups that are threatened is useful for targeting areas for further consideration. Identifying species threatened by climate change and pollution is essential for prioritising focus areas. 	 The infinitions of using the fock threatened species list, e.g. invertebrates currently form only 32% of all animal assessments on The IUCN Red List (As many as 1 in 5 invertebrates may be considered threatened). The Global and Country Analysis may be underplaying certain pollution categories, e.g. water quality problems in many of South Africa's rivers. The analysis does not explicitly separate terrestrial and freshwater systems by hotspots. Further inputs are required to prioritize specific systems for interventions. There is a need to re-analyse using the same data, but excluding marine species – this was alluded to in the Global Analysis for South Africa but not addressed in the Country Analysis. (see Figs. 3-4)' Habitat loss is equally or more important than climate change for restricted-range species but this has not been factored into the analysis. Correlation between pollution category and species may be misleading: (i) limited species associated with solid waste, downplaying this issue (Categories 9.1.1-2; Figs. 9-10; Tables 4-5)'. Chemical spills, which are common occurrences in South Africa, are not listed as a pollution category under Category 9.2'. Category 9.6' dealing with Excess Energy is not currently mapped, e.g. light pollution that impacts nocturnal species such as birds and glow worms. Maps for specific categories (9.3 Agriculture & Forestry effluents: Figure 14; 9.3.3 Herbicides & Pesticides: Figure 17)' appear to be too general for targeting all areas of impact.

6.2 Lessons learned and recommendations for next phase of project

Firstly, the success of the workshops was based on a high level of engagement between the research team and JNCC. While the Information Package was extremely useful, it required inputs from a multi-disciplinary team to ensure that the content was presented to the participants in a digestible format. Participants displayed informed levels of awareness of climate change and understanding of pollution and were highly appreciative of JNCC's and the SA partner's decision to engage them. It was clear that a number of sectors affected by/interested in pollution are concerned about its impacts but they are also facing other challenges, most recently the COVID-19 pandemic. Nevertheless, the project and more importantly Global Analysis was viewed as having value and was considered an urgent initiative. The role of national government and industry in implementing the recommendations that emerge from the project was highlighted by participants in several instances.

The research team is confident that saturation was reached in the second workshop and the information/data gathered is adequate and of sufficiently good quality to have been used to inform the future of the project. While the workshops provided insight into the content of the local analysis and served as the primary mechanism to gather inputs from the participants on the value of the analysis, they took an enormous amount of time and effort to organise and roll-out using an online format, given that no existing stakeholder database was available.

Going forward, and particularly in terms of disseminating the final findings of the project, we believe that a selection of diverse communication platforms will be useful, and a target group-based approach is suggested. Of particular value will be a provincial-based approach which forms part of a National Awareness Campaign on the effects of pollution. Other considerations include:

- Careful attention must be paid to using the right language, selecting culturally sensitive and context-specific messages and delivering these using appropriate platforms when disseminating the findings of the project.
- There is a need to engage with citizens (stakeholders) early in life either directly or indirectly (ensuring prior learning) possibly through schools.
- There is a need to supplement the data used for the local analysis using existing databases and future research focused on established pollutants that pose a major threat (example those within the Industrial and military and Domestic and urban wastewater categories), emerging pollutants (endocrine disruptors and light pollution) and taxa (e.g. plants) that are under-represented in the IUCN database.

While the workshops focused largely on the environmental and public sectors, this project presents an opportunity to encourage a country-wide approach to mitigate pollution impacts. It is hoped that the findings and recommendations of the project will inspire multiple sectors to buy-into the goals of a National Pollution Mitigation Strategy (and embedded awareness campaign) are recommended. Finally, the data collected during the workshop provide strong motivation for capacity building initiatives around pollution mitigation, particularly at the community level.

7. Hyperlinks

Descriptive text	Link	Page number
South African Air Quality Information System	https://saaqis.environment.gov.za/	30
miniSASS	www.minisass.org	30
Freshwater Biodiversity Information System	www.freshwaterbiodiversity.org	30
Virtual Museum	https://vmus.adu.org.za/	30
Southern African Bird Atlas Project 2	www.sabap2.birdmap.africa/	30
Coordinated Waterbird Counts	www.cwac.birdmap.africa/	30
South African Waste Information Centre	www.sawic.environment.gov.za/	30

8. References

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9. Appendices

9.1 Appendix 1 – Workshop Schedule

- 1. Introductory definition slides loop for first 3-5 minutes Wesley
- 2. Google form for Workshop Questionnaire emailed to all participants Wesley
- 3. Welcome and introduction to project, data protection measures and data collection methods for workshop Sershen
 - Start recording meeting -Simlindile
- 4. Trial for polls and Polly emailed to all participants Wesley
- 5. Introduction to local sense video Sershen
 - Local sense video will be played for you now (video is 26 minutes long) Wesley
 - Provide YouTube link for video in chat box Wesley

(After video is complete, allow 2 minutes for YouTube people to finish watching)

- 6. Open floor for questions, clarifications etc. Sershen
- Commence with questions (those highlighted in yellow are polls administered via Polly/Chatbox/Google Form); questions that are not administered via the polls will be posed verbally by facilitator and participants can answer verbally or via the chatbox.:
 - i. What other projects in South Africa are you aware of that are looking at pollution threats to biodiversity? Please provide details.
 - ii. Are there any other factors in South Africa that should be considered when assessing pollution e.g., socio-economic, climatic, political?
 - iii. Are the results of the analysis a realistic reflection of the proportion of species threatened by pollution in South Africa?
 - Yes/No

If no, please explain.

iv. To what extent does the data reflect the current situation in terms of the types of flora and fauna threatened by pollution in South Africa?



vii. What degree of investment is being made by funders/donors in pollution-related research?



- xi. What pollutants in your opinion need to be mitigated in South Africa and how?
- 8. Open floor for any questions/comments/suggestions from participants.
- 9. Thank participants and alert them to post-workshop questionnaire that they will be receiving.

Thank you so much colleagues for making the time and contributing to these very fruitful discussions. Stay safe and go well.

9.2 Appendix 2 – Workshop Questionnaire

1. What other projects in South Africa are you aware of that are looking at pollution threats to biodiversity? Please provide details.

2. Are there any other factors in South Africa that should be considered when assessing pollution e.g., socio-economic, climatic, political?

3. Are the results of the analysis a realistic reflection of the proportion of species threatened by pollution in South Africa?

3b. If no, please explain

4. To what extent does the data reflect the current situation in terms of the types of flora and fauna threatened by pollution in South Africa?

5. Are there any major and/ or emerging pollution threats in South Africa that weren't included in the analysis?

6a. How much effort is being put into pollution mitigation/characterization in the country?

6b. For which pollutants and by who?

7. What degree of investment is being made by funders/donors in pollution-related research?

8. What degree of investment is being made by funders/donors in pollution mitigation?

9. Are the data analyses applied suitable/useful? Please explain

10. What types/sources of data are presently guiding decision-making around pollution in the country?

11. What pollutants in your opinion need to be mitigated in South Africa and how?

9.3 Appendix 3 – Post-workshop Questionnaire

- i. Name
- ii. Sector
- iii. Province(s) where you work/have knowledge of pollution and/or biodiversity

1. What would you say your level of expertise in pollution is? (Include examples of your involvement in pollution management and whether you have a general or specific area of knowledge of pollution.)

2a. Which province(s) do you think exhibit pollution hotspots and/or pollution threats to biodiversity?

2b. Provide details

3. Are there any other factors in South Africa that should be considered when assessing pollution? e.g., socio-economic, climatic, political.

4. From the categories below, which pollutant threats do you think pose the greatest threat to species? (Use the following scale: 1 = lowest threat to species, 6 = highest threat to species) [Agriculture and forestry effluents]

5. Please identify the three main organisations/entities responsible for managing pollution in South Africa.

6a. Are the results of the analysis presented a realistic reflection of the proportion of species threatened by pollution in South Africa?

6b. Please provide details

7a. Is your opinion based on experience or published data?

7b. If data – please include references of information sources. (e.g. article, database, report etc.)

8. Are there any major and/ or emerging pollution threats in South Africa that weren't included in the analysis?

9a. Is the interaction between pollution and climate change reflected for South Africa in terms of threat to species a realistic representation?

9b. If no, please explain

10. To what degree can reducing pollution affect the South African economy and livelihoods in the country?

11. What information should be made available to decision-makers to mitigate pollution?

12. Which organisations/entities should champion the mitigation of pollution in South Africa?

9.4 Appendix 4 – Workshop Session A Minutes



Stakeholder Engagement Workshop: Session A

1. Local sense video [Played]

- 2. Open floor for questions, clarifications etc.
- Participants noted that solid waste is not as big of an issue as it is made to be.
- Participants requested information on how the data was collected and the INR team noted that links for methods and database would be provided. This information is from IUCN.
- Participants shared that sentiments shared on ecological risks, requested information on
- Participants noted that the lack of service delivery results in waste such as nappies being disposed of at freshwater sources which are also the communities' water sources. This poses a health risks to the communities and their livestock.
- Participants noted that specifically for plants, indigenous plants could be more adapted to
 polluted environments that's why they are the first choice to mitigate pollution. Hence,
 extinction is critical in long term mitigation although exotic species could be quicker to
 occupy polluted environments.
- 3. Workshop Polly

Questions

i.	a) Are th	e result	s of the	analysis	a rea	alistic	reflection	of the proportion of spec	ies	
	threaten	ed by p	ollution	in South	n Afri	ca?				
	Yes/No									
	b) If no,	please e	explain.							
ii.	To what	extent	does the	e data re	flect	the c	urrent situ	ation in terms of the type	s of flo	ira
	and faun	a threa	tened b	y polluti	on in	Sout	h Africa?			
0			-0				0	0		
Very Li	ttle		Little	;		ļ	Neutral	Large		Very Large
111.	a) How	much	effort	s bring	put	into	pollution	mitigation/characterizati	on in	the
0	country?		0			C		0		-0
Very Little		l	ittle			Neu	tral	Large	١	/ery Large

b) For which pollutants and by who?

iv. What degree of investment is being made by funders/donors in pollution-related research?

0	0	0	0	
Very Small	Small	Moderate	Large	Very Large





v. What degree of investment is being made by funders/donors in pollution mitigation?

0	0	0	0	0
Very Small	Small	Moderate	Large	Very Large

- vi. Are there any major and/ or emerging pollution threats in South Africa that weren't included in the analysis?
- Participants noted that Primary impacts of Agricultural run-off, sewerage runoff. There
 are Endocrine disruptors and that Contaminants should be kept in mind when assessing
 impacts.
- Participants noted that Spillages Chemical spillages are prevalent in South Africa- e.g. Umhlatozi spill.
- Participants noted that Micro plastics needs to be included as a major concern in soil, freshwater etc.
- vii. What other projects in South Africa are you aware of that are looking at pollution threats to biodiversity? Please provide details.
 - DWS: Rehabilitation and Remediation Management Guidelines for Water Resources
 - SALGA has pollution / waste related projects
 - Platics SA Operation Clean Sweep OCS ensure all plastics producers and converters don't spill plastics materials into the environment e.g. drain system (Stewardship Project)
 - Sustainable Seas Trust working on plastic pollution
 - One health Approach to disposable nappy' Research based project. Covers: Limpopo, Mpumalanga, Eastern Cape and KZN for now. Lead by Ngo's such as Endangered Wildlife Trust, Conservation South Africa.
 - Plastics SA work closely with Prof Peter Ryan (UCT) do a plastics pollution survey every 5 years along SA coastline
 - DWS: National Eutrophication Strategy
 - Various stewardship projects with NPOs such as WWF-SA and CSA also, Mapping of waste hotspot in rural EC with the aim of advocating for waste management policy and service delivery.
- viii. Are there any other factors in South Africa that should be considered when assessing pollution e.g., socio-economic, climatic, political?
 - Non-compliance and no accountability
 - Lack of proper discard of waste (e.g. umbogitwini area)
 - Service delivery not in place in rural landscapes (rural enterprises contribute to pollution)
 - Human health risk assessments associated with pollutants is another important factor to include.
 - Plastic pollution: need of upscaling of management of waste in municipalitiesbudgeting, training, management. (Guidelines are being developed for waste management)





- African Marine Waste Network Sustainable Seas Trust re waste management education and awareness and training (waste Academy)
- ix. Are the data analyses applied suitable/useful?
- Participants expressed that the Data analysis is useful- but cautioned that it needs to be fine-scaled/tailored for each institutional audience
- Participants expressed that the data analysis all is great data is important and useful and
 expressed appreciation for the well-researched data that can be used to sensitize the
 industry and it can be used assist with project identification and strategies to ensure no
 plastics enter the environment
- x. What types/sources of data are presently guiding decision-making around pollution in the country?
- Data from other organisations-e.g. material flow from CSIR
- Various government departments have data on decision making related to pollution or the country (national, district, local etc.)- real time data systems
- Municipal data that can be accessed
- Routine monitoring data (national programs e.g. on water quality, national chemical monitoring programs). But also, Compliance data from WUL etc. However still waiting for implementation of the Waste Discharge Charge System. Occasional targeted research data from relevant academic institutions.
- https://cwac.birdmap.africa/ Welcome to the Coordinated Waterbird Counts (CWAC) since 1992
- Environmental health units they have seperate sections dealing with waste and air quality
- South African Waste Information System (SAWIS)
- Air quality monitoring which does occur on a regular basis and reports are available should anyone require them
- xi. What pollutants in your opinion need to be mitigated in South Africa and how?
 - Bacteria (e.g E.Coli) through better compliance of wastewater treatment works. Industrial pollution through better compliance monitoring by government as private monitoring by companies is seldom shared
 - SOX, NOX, PM
 - Organophosphate pesticides
 - plastics, hydrocarbons and pesticides.
- large scale agricultural chemical use in food production encourage use of local food security production systems
- Particulate matter borne potentially toxic elements (such as chromium, nickel, aluminium), and designing green spaces using tolerant plant species is essential in mining/industrial regions.
- Adopt-a-River NPC local water testing on uMngeni Estuary

xii. Open floor for any questions/comments/suggestions from participants

Participants noted that a focus on plastics may act to divert focus from other impacts with more significant health impacts (heavy metals, sewage impacts, acid mine drainage etc). Furthermore, plastic mitigation initially focussed on straws which are a VERY minor contributor to impacts.

9.5 Appendix 5 – Workshop Session B Minute



Stakeholder Engagement Workshop: Session B

- 1. Local sense video [Played]
- 2. Open floor for questions, clarifications etc.
 - Participants expressed their Initial perceptions and thoughts and noted that data sources, currency of data and scale of data must be taken into consideration for such research. They further noted that often grey literature is overlooked.
 - Participants commended that the data analysis handles a combination of pollution impacts (without categorising the pollutants).
 - Participants noted that there seems to be a preponderance of fish especially that are
 threatened and less so on the smaller land-based spp. They noted that this could be due
 to a shortage of research in that field, there by distorting the data currently presented?
 - Modelling tools have potential for synergistic and cumulative impacts of pollution. Modelling is important to consider.
 - There is a lack of in-situ measurements (like dam turbidity, chlorophyll etc). An option is to better use satellite imagery for larger water bodies. Modelling provides useful forecasting of impacts based on land-use contributions. (https://communities.unep.org/download/attachments/50626608/9_WWQA_Africa%20 Use%20Cases_Lake%20Victoria%20%26Volta%20Basin_Presentation.pdf?version=1&mo dificationDate=1613503956915&api=v2)
 - Further to the questions.....the investment and effort in research is not necessarily
 proportionate to investment and effort in implementation towards mitigation

Workshop Polly

Questions

i.	a) Are the resu threatened by Yes/No b) If no, please	Its of the analy: pollution in Sou explain.	sis a realistic reflection uth Africa?	of the proportion of species	
II.	To what extent and fauna three	does the data atened by pollu	reflect the current situation in South Africa?	ation in terms of the types of	flora
0		0	o	0	0
Very Li	ttle	Little	Neutral	Large	Very Large
iii. o	a) How much country?	effort is beir	ng put into pollution	mitigation/characterization	in the
Very Little		Little	Neutral	Large	Very Large

b) For which pollutants and by who?

iv.	Joint Nature Conservation Co What degree of investment	mmittee	funders/donors in p	ollution-related
	research?			
0	0	0	0	o
Very Small	Small	Moderate	Large	Very Large
v.	What degree of investment is	being made by funde	ers/donors in pollution	mitigation?

vi. Are there any major and/ or emerging pollution threats in South Africa that weren't included in the analysis?

Moderate

Large

0

Very Large

- Hydrocarbons, chemically associated soil pollutants that pollute riparian zones and eventually the coast.
- Pharmaceuticals and endocrine pollutants-need long term studies which may be challenging in generating data.
- Light pollution- impacts glowworms and nocturnal species- need to expand on this research/data.
- vii. What other projects in South Africa are you aware of that are looking at pollution threats to biodiversity? Please provide details.
 - Recently published studies for Cape Town water quality, particularly identifying sewage as a major problem. But studies do not explicitly link to biodiversity.
 - Arasacom catchment project- that looks at water quality

Small

0

Very Small

- viii. Are there any other factors in South Africa that should be considered when assessing pollution e.g., socio-economic, climatic, political?
 - Participants noted that a holistic view and systems thinking is important especially the consideration of socio political and governance issues: compliance, failing infrastructure, actual sources of pollution.
 - The level of functionality of municipalities is critical, and capacity to enforce legislation is also important.
 - Climatic conditions need to be taken into consideration especially changes in biophysical and chemical processes.
 - Issue of sedimentation must be taken into consideration as it may be caused by knockon effects.
 - Invasive species are significant and must be considered when assessing pollution
 - Participants further noted that impacts of pollution must not be separated from a combination of other contributors/threats to humans, animals and plants.
- ix. Are the data analyses applied suitable/useful?
 - Participants noted that the maps looked basic and this may mean that the analyses were basic and suggested that perhaps, the team could consider adding other categories that would highlight more threats.
 - Disaggregation of pollutants was noted as something that made the data analysis useful.
 - Participants noted that discipline biases are critical for data interpretation and analysis





- Participants noted there is a need for a more in-depth understanding of IUCN conceptualization and categorization.
- x. What types/sources of data are presently guiding decision-making around pollution in the country?
- Data on risks which focus on water quality and the socio-political-economic issues are not factored in. It is important there is integrated data interpretation. This data should be drawn from local sources such as municipalities, national resources: water and sanitation departments, environmental affairs departments- these often work in silos.
- CSIR- tracking pollution
- Ethekwini municipality
- There are also national government departments DWS and DFFE
 Often reports such as WRC, Umgeni Water, dept of Agric, etc. grey literature maybe sources to lead to further databases
- Participants noted that interpretive analysis of solid waste disposal volumes, recycling volumes, SASS5 data collection (pooled), NGO clean-up info (based on volumes), environmental audits that collect usage of agro-chemical usage by area to determine over- or under-application etc. could become useful tools for guiding decision making [One may look at the South African Waste Information Centre by DFFE for solid waste disposal data http://sawic.environment.gov.za/South African Waste Information Centre]
- Local and indigenous knowledge systems- community meetings, FGDs, direct stakeholder engagement.
- Ambient Air Quality Monitoring instruments are used by Government to monitor air pollution. In Mpumalanga there is government-owned monitoring station placed in the air pollution priority areas (Witbank, Ermelo, Secunda etc)
- Citizen science aspect, Citizen science (like http://www.minisass.org/en/) may be of value
- 1. What pollutants in your opinion need to be mitigated in South Africa and how?
 - Discharge of untreated sewage by municipal pump stations which are failing and discharging directly into the coastal waters.
 - Litter which is wide spread has significant impact in contributing to water and land pollution, microplastics in the environment; result in flooding
 - Mutagens-pollutants that cause mutations- heavy metals, endocrine disruptors.
 - Air pollutants impact on vegetation impacts can be significant at ecosystem level
 - Solid waste, Illegal littering and dumping, over-use of agro-chemicals, sewage and effluent discharges.
 - Litter from rural communities which is a source of solid waste which ends up in the river system.
- 2. Open floor for any questions/comments/suggestions from participants
 - Participants noted that taxa identification is important for this analysis. Participants suggested a process of identifying and mapping the taxa and overlaying that to figure out species in the area affected by pollution then focus on distributions. The analysis should, perhaps, be more targeted and not general.
 - Participants highlighted that stakeholder representation for this type of research must be adequate for developing recommendations.