Final Evaluation Report

Your Details	
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Project Title	Effects of protected areas on freshwater fish conservation: A case study of National Parks in the Zambezi River basin, Zimbabwe
Application ID	27654-1
Grant Amount	£4,977
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Date of this Report	27 December, 2021

1. Indicate the level of achievement of the project's original objectives and include any relevant comments on factors affecting this.

Objective	Not achieved	Partially achieved	Fully achieved	Comments
Generation of ecological data on freshwater habitats located inside and outside protected area boundaries.				We collected ecological data on fish biology, habitat characteristics, physical water parameters, and water chemistry. Data was collected from a total of 42 sampling stations associated with seven protected areas namely, 1. Mana Pools, Matusadonha, Matopos and Kariba National Parks, and 2. Kyle, Sebakwe, and Chivero Recreational Parks. However, we had to change our target study area from primarily focusing on protected areas in the Zambezi basin to include protected areas in Limpopo and Save basins due to extreme drought conditions prevalent during the summer 2019 fieldwork. Due to the drought, most of the accessible tributaries to the middle and lower Zambezi basins were completely dry.
Mapping distribution patterns of Zimbabwe's ichthyofauna				We scaled up this objective to focus on distribution patterns of freshwater fishes in the whole of Southern Africa. Fish occurrence data collected during the field season was used to complement existing datasets from several literature sources to create an updated freshwater fish incidence data matrix for 19 major drainage basins in the whole Southern Africa subregion. Using the updated matrix, we conducted a quantitative review of biogeographical zonation patterns of Southern Africa's ichthyofauna. The same matrix was also used to investigate decomposed components of beta diversity including species turnover and nestedness patterns across the 19 major drainage basins. A draft manuscript using these data is in

				the final internal review stages pending submission to an international peer reviewed journal by the end of this year.
Mercury exposure in fish from protected and non-protected reservoirs				Using fish muscle tissue, we assessed total mercury concentrations (THg) in fish from protected and non-protected reservoirs to determine the impact of anthropogenic activities such as artisanal small scale gold mining on aquatic and human health between the two sites. Aquatic health of reservoirs in protected and non – protected areas was assessed based on mercury biomagnification patterns. THg concentrations for fish from protected and non-protected reservoirs were compared with international standards to determine their potential impact on human health. A draft manuscript using THg data in fish from protected and non-protected reservoirs is in its final stages of internal review pending submission to an international peer reviewed journal.
Genetic structuring of Zimbabwe's ichthyofauna across major drainage basins.				We collected fin clips from two co-distributed species (*Clarias gariepinus* and *Labeo cylindricus*) with an extensive range covering all four major drainage basins in Zimbabwe -- (Middle Zambezi, Lower Zambezi, Limpopo and Save). We extracted DNA from the fin clip tissues and used two mitochondrial molecular markers, cytb and COI to compare DNA sequences from the discrete populations and determine the extent of genetic variation across the four basins. For this objective, no draft manuscript is available yet as we are still analysing the genetic data.
Engaging Zimbabwe's natural resource conservation agencies on freshwater biodiversity conservation				We had fruitful meetings (both formal and informal) with officials from the Zimbabwe Parks and Wildlife Management Authority at all the seven protected areas we visited during fieldwork. However, we are still to present our consolidated findings to

				the ZPWMA to elaborate the significance of our work to the conservation of freshwater biodiversity in Zimbabwe. We also plan to engage the Environmental Management Agency (EMA) on mercury contamination in Zimbabwean freshwater ecosystems.
Raising awareness on freshwater fish conservation to local communities living in riparian zones				We had informal meetings with community members (especially artisanal fisherman and traditional leaders) at some of the sampled sites (Chivero, Kariba, Sebakwe, Kyle and Matopos). Matusadonha and Mana Pools National Parks are in very remote areas infested with tsetse flies and characterised by an unconducive climate and poor soil fertility for agriculture. Therefore, there were no human settlements easily accessible to the research team.
Website design				We need to generate more content to fulfil this objective. We believe that the combined effect of more scholarly research output, community outreach programmes, and stakeholder engagement will generate better content to be posted on the website.
Publication of non-scientific article				We thought it was a good idea to make a non-scientific article based on our published scholarly manuscripts. Our plan is to engage the newspaper and magazine editors once our first scientific articles are published in peer reviewed journals.

2. Please explain any unforeseen difficulties that arose during the project and how these were tackled.

Zimbabwe was experiencing a severe drought in the summer of 2019 when we conducted the fieldwork. Our original proposed study sites (protected areas in the Zambezi basin) are in the country's agroecological region 5, which (even in good rainfall seasons), receives the least amount of rainfall (mean annual precipitation <650 mm). All the streams and pools associated with the protected areas were dry except for very large rivers (e.g., Zambezi, Sanyati and Ume) and deep pools (e.g., Chishashiko and Long Pool in Mana Pools) which still had standing or flowing water. We decided to expand our focus to include other protected areas in less drier parts of the country and in the process, added the following new objectives to our original study plan:

a. Genetic structuring of Zimbabwe's ichthyofauna across major drainage basins

We sampled fish from protected areas on either side of the central ridge (a highland plateau which separates headwaters of rivers flowing towards the Zambezi to the north from those flowing in the southerly direction as parts of the Limpopo and Save drainages). Using pectoral fin clip tissues from fish populations belonging to two species (*Clarias gariepinus* and *Labeo cylindricus*) that are found on both sides of the divide, we extracted DNA and used mitochondrial DNA markers (Cytb and COI) to determine the extent to which topography has influenced genetic structuring of populations for those two species.

b. Mercury exposure in fish from protected and non-protected reservoirs

We sampled muscle tissue from fish in different feeding guilds from reservoirs in protected and non-protected areas. We then quantified the extent of mercury biomagnification and the potential risk of elevated mercury levels to both aquatic and human health.

The outbreak of Covid-19 in 2020 and the associated travel restrictions meant that we could not travel to Zimbabwe for another field sampling trip. Instead, we used the resources and time to concentrate on laboratory work, including DNA extraction, amplification, and sequencing for the phylogeography analysis, and THg spectrophotometry and stable isotope analyses for the mercury exposure evaluation.

3. Briefly describe the three most important outcomes of your project.

a. Updated biogeographical zonation patterns

We collated distribution data from our fieldwork with existing published and grey literature on fish distribution in Southern Africa to construct an updated incidence matrix for all freshwater fish in Southern Africa. We then used the matrix to make a quantitative revision of bio-regionalisation patterns. This work will serve as a benchmark for future studies focusing on fish distributions at larger spatial scales (e.g., basin and sub-basin levels) in the region.

b. Mercury trophodynamics

Our work on mercury biomagnification provides the first study in Zimbabwe to determine mercury trophodynamics in aquatic ecosystems. Using international standards of mercury toxicology, we determined the levels of Hg exposure to fish assemblages from protected and non-protected areas. Through the same study, we were also able to provide the first fish consumption advisories to communities that consume fish from reservoirs located in both protected and non-protected areas.

c. Population genetic structuring

Our work on genetic variation of co-distributed species provides the first phylogeographic assessment of fish populations in Zimbabwe. Although analysis is still ongoing, results from this study will provide important information on how genetic diversity can be conserved to maintain the evolutionary potential of freshwater fish species.

4. Briefly describe the involvement of local communities and how they have benefitted from the project.

Since our project also involved sampling water bodies outside protected areas, we interacted with traditional leaders to seek permission to work in their areas of jurisdiction. We had both formal and informal meetings with the leaders and community members to explain the nature of our project and how it benefited conservation of local freshwater resources. Some of these discussions, especially in Matabeleland province (in communities around Matopos National Park) were very engaging since water is a very scarce resource in that region. Community members helped us to locate some of the few reservoirs that still had water and, in some cases, also assisted with sampling. In Sebakwe, Mazowe and Chivero areas, we interacted with several artisanal fishermen who operated fishing co-operatives. The common sentiment among all the fishermen from these areas was declining fish catch. We used the platform to educate them on the importance of setting aside reserve areas to allow recruitment of fish stocks and the use of appropriate gear that does not target young of the year and juvenile fish.

Two undergraduate students from local universities were part of the fieldwork team at different stages of the project. Joana Banda, who studied BSc Forest Resources and Wildlife Management at the National University of Science and Technology (NUST), helped with sampling water bodies inside and outside Matopos National Park. Joana also doubled as a translator when we reached out to communities outside the park where one of the native languages (Isindebele) was spoken. Yvonne Mudzengerere, who studied BSc Natural Resource Management at the Bindura University of Science Education (BUSE), assisted with sampling sites inside and outside Chivero Recreational Park. Both students were taught fish sampling techniques (including electrofishing and seine netting) and collection of water quality parameters (secchi depth, conductivity, pH, turbidity, dissolved oxygen, and water temperature). The students also collected data for their personal research projects during the expedition.

5. Are there any plans to continue this work?

We have data for the dry season only and plan to capture seasonal variation in fish abundance across the sampled sites. We also plan to extend sampling to other parts of the country that are not represented in the current dataset. These include the north-eastern and south-eastern regions of Zimbabwe. A complete dataset will allow us to create spatial models that inform the most relevant environmental and habitat characteristics explaining fish abundance. These models will then allow us to identify areas that may be suitable for the development of freshwater protected areas.

We also plan to expand the sampling scope for the fish toxicology analyses to include more reservoirs and fish species. A broader dataset will help us to understand the trophodynamics of mercury and other heavy metals in Zimbabwe's aquatic ecosystems and the associated impacts on both aquatic and human health. We also hope that our findings from the toxicology project will help to provide evidence to support the development of freshwater protected areas in Zimbabwe.

6. How do you plan to share the results of your work with others?

Two draft manuscripts on: 1. "Biogeographic and beta diversity patterns of southern Africa's freshwater fishes", and 2. "Mercury exposure in fish assemblages from protected and non-protected areas" are in the final stages of internal review pending submission to international peer reviewed journals by the end of January 2022. Non-scientific articles based on published manuscripts will be submitted to local magazines and newspapers in Zimbabwe. We also hope to present some of our work at international conferences, including the Student Conference on Conservation Science-New York in 2022. We will also request a platform to present our findings to the Zimbabwe Parks and Wildlife Management Authority to make a case for the establishment of freshwater protected areas in Zimbabwe.

7. Timescale: Over what period was the grant used? How does this compare to the anticipated or actual length of the project?

The grant funds were used over about 8 months, and funds mainly covered the fieldwork component of the project. The project is still ongoing, and the PI has immensely benefited from collaborations and other grants to conduct laboratory analyses of exported samples (i.e., DNA extraction, amplification and Sanger sequencing, plus total mercury and stable isotope analyses).

8. Budget: Provide a breakdown of budgeted versus actual expenditure and the reasons for any differences. All figures should be in £ sterling, indicating the local exchange rate used. It is important that you retain the management accounts and all paid invoices relating to the project for at least 2 years as these may be required for inspection at our discretion.

Item	Budgeted Amount (£)	Actual Amount (£)	Difference (£)	Comments
Transport Costs				
Car hire	1395	1279	-116	We got a cheaper option and used the savings on other expenses.
Fuel	388	1266	+878	Fuel was scarce during summer 2019 and we relied on informal channels where prices were higher than average pump prices. Also, our initial budget did not account for the following, 1. boat fuel and 2. electrofisher fuel –the fisher was powered by a generator, which used gasoline. The rugged terrain we travelled, specially to reach Mana Pools and Matusadonha

				National Parks, required a lot of fuel.
Toll gates		42	+42	Toll fees were not accounted in our initial budget.
Shipping costs		281	+281	Due to a rough terrain and poor road network, we had to take a ferry from Kariba to Matusadonha National Park. This amount paid for our car, luggage, and passenger fares for the research team.
Parking fees		6	+6	We had to pay parking fees in major cities where we shopped for food supplies.
Field car repairs		35	+35	Due to the long distances that we travelled; we needed a minor service to the vehicle.
Accommodation				
Accommodation fees	1395	388	1007	The following national parks that we visited waived accommodation charges, providing us with free lodging -- Kyle, Sebakwe, Chivero, Matusadonha; we channelled the savings to other expenses.
Conservation fees		154	+154	We had not accounted for this expense in our initial budget.
Park entrance fees	93	19	-74	Only vehicles were charged and there was no separate charge for the passengers. We used the savings on other expenses.
Food and field gear				
Food	1163	925	-238	We bought our own food supplies and prepared our meals. This was cheaper than buying prepared meals, and we used the savings for other expenses.
Equipment hires	465	465		
Chemicals and consumables		495	+494.6	We bought absolute ethanol. formaldehyde, MS222 anaesthetic, buckets, gloves, collection vials and nylon ropes.
Camping Gear		341	+341	We bought tents, sleeping bags, inflatable mattresses, and cooking utensils.
Field expendable supplies		1258	+1258	We had to buy the following items not in the initial budget; minnow traps and seine nets, oxygen and pH probes, roof rack, GPS unit, life

				jackets, cotton braided ropes, solar lanterns, digital scale, and metal jerry cans for carrying fuel.
Permits & Insurance				
Collection permit	78	426	+348	Contrary to how we had budgeted, the collection permit was charged per National Park.
Export permit		78	+78	This was a requirement for transporting fish muscle and fin clip tissues to the USA.
International Health Insurance		89	+89	This was a requirement from the PI's college in case we had a major accident that required specialised healthcare.
Total	**4977**	**7547**	**+2570**	We used personal funds and money from other grants to cover the difference. Exchange Rate – (£1 = USD 1.29)

9. Looking ahead, what do you feel are the important next steps?

- Publishing the completed draft manuscripts in international peer reviewed journals and presenting major findings at international conferences.
- Results will constitute various chapters of the developing doctoral dissertation of the PI at SUNY-ESF; anticipated graduation in early summer of 2022.
- Extending our sampling efforts to capture seasonal variation and data from the eastern parts of the country.
- Running models with collated data on species richness, abundance, endemism, water quality, and a suite of environmental parameters to determine areas most suitable for the establishment of freshwater protected areas in Zimbabwe.
- Conducting surveys to quantify fish consumption patterns in communities impacted by artisanal small scale gold mining and using those data to determine whether the current levels of mercury exposure through fish consumption surpass provisional weekly dietary intake (PWDI) levels.

10. Did you use The Rufford Foundation logo in any materials produced in relation to this project? Did the Foundation receive any publicity during the course of your work?

The logo will be used at upcoming conferences and seminar presentations. The foundation is also gratefully acknowledged in the two draft manuscripts, which are almost ready for submission to international peer reviewed journals.

11. Please provide a full list of all the members of your team and briefly what was their role in the project.

Name	Role	Duties
Joseph Makaure	Principal Investigator	Conception of project ideas, specimen collection, IACUC and export permit applications, field specimen collection, laboratory analyses, data analyses, lead author on all scientific articles
Dr Trevor Dube	Field Logistics	Scholarly reviews on manuscripts, Assisted with fieldwork logistics – accommodation, transport, food, and specimen collection.
Patrick Mutizamhepo	Technical Field Support	Led electrofishing and gill netting operations
Joanna Banda	Field support (Undergraduate)	Language translation, specimen collection and preservation
Yvonne Mudzengerere	Field support (Undergraduate)	Specimen collection and preservation
Abbey Webster	Toxicology Lab support	Technical support for total mercury and stable isotope analysis
Dr David Bullis	Molecular Lab support	Technical support for molecular analysis
Dr Donald Stewart	Academic Advisor	Scholarly reviews on manuscripts, provided field equipment for specimen collection
Dr Rebecca Rundell	Academic Advisor	Scholarly reviews on manuscripts, provided laboratory facilities for molecular analyses
Dr Roxanne Razavi	Collaborator	Provided sampling material for fish muscle tissue and funding for processing mercury samples

12. Any other comments?

We are very grateful to The Rufford Foundation for the financial support that enabled these analyses to be realised. Such support is key for enabling resident scientists in developing regions (where resources are usually limited) to conduct in-depth scientific studies on biodiversity conservation. The opportunity also enabled us to forge new networks with individuals, institutions, agencies, and communities involved in some capacity with conservation of Zimbabwe's biodiversity. The networks will be key for the next phase of project implementation.