Expedition Buteng: multi-disciplinary aquifer conservation in Southeast Sulawesi

Nixie Expeditions

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Expedition Report

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Rannvá Jørmundsson explores the Laulawi cave aquifer (Alex Dawson 2024)

OVERVIEW

Expedition Buteng set out to explore and study the Laulawi Aquifer and its associated cave systems on Pulau Muna Island (5° 15’ 13.118” S, 122° 31’ 57.922” E), Southeast Sulawesi, Indonesia. This interdisciplinary mission combined cave exploration, biodiversity assessment, and hydrological and geological investigations with community outreach efforts.

Key achievements include:

Mapping and Surveying

We explored and surveyed 5.2 kilometers of the flooded Laulawi cave system, making it currently the longest underwater cave system in Southeast Asia. Additionally, we documented 22 dry caves and mapped five of them.

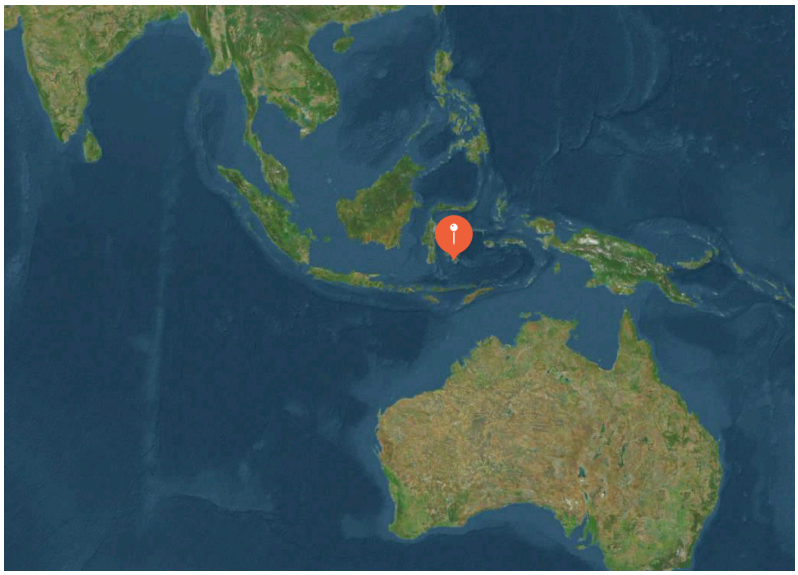
Scientific Sampling Program

We collected water, sediment, eDNA, and geological samples to support research on biodiversity, groundwater protection, and a potential future UNESCO Geopark application.

Community Outreach and Cultural Heritage

We organised events in Lasongko village to raise awareness about the aquifer’s significance and promote the UNESCO Geopark application for Muna Island. We also conducted a quantitative ethnographic survey to understand local relationships with and needs surrounding water. Furthermore, we broadcasted three live classroom sessions to engage students with real-time fieldwork.

This expedition contributed to global scientific knowledge with a strong emphasis on local community involvement and environmental stewardship.



Expedition location: Pulau Muna, Indonesia (Apple Maps 2025)

INTRODUCTION

Paying tribute to the local abbreviation for the Buton Tengah Regency as our namesake—*Buteng*—Expedition Buteng set out to deepen scientific understanding of the hydrology, biodiversity, and geological significance of the Laulau cave system and freshwater aquifer on Muna Island. By combining cave divers, speleologists, scientists, and local communities, our mission fostered collaboration for environmental preservation.

Our primary goals included:

- Mapping the Laulawi Aquifer and associated caves to better understand the region's hydrological and geological dynamics.
- Collaborating with Gadjah Mada University (UGM) to support studies in cave hydrology, speleology, geomorphology, and biology.
- Engaging Buton communities in the expedition to emphasize the importance of water and caves in their cultural heritage and support their aspirations for UNESCO Geopark status.
- Through this collaboration, the expedition not only advanced scientific knowledge and empowered local communities to contribute to conservation efforts.

Mapping and planning meeting; (L-R) Rannvá Jørmundsson, Audita Harsono, Tamara May, David Mayor, Maria Bollerup, Arie Sapputra (Tom Lindboe 2024)

Professor Eko Haryono (L) and Robin Cuesta (R) discussing cave formations (Tom Lindboe 2024)

EXPEDITION ACTIVITIES & CHALLENGES

Expedition Buteng involved rigorous scientific exploration, with daily data collection and community engagement.

Key activities included:

1. Cave Surveying and Mapping

We surveyed the Laulawi cave system using specific protocols both for the flooded and dry parts. The surveys followed a methodology that ensured scientific accuracy, using equipment such as high accuracy GNSS systems, laser pointers, clinometers, underwater measuring devices, and specialized diving equipment, including closed circuit rebreathers (CCR) and diver propulsion vehicles (DPV). We mapped both the flooded and dry cave systems, totaling 5.2 kilometers of underwater cave and 22 dry caves.

2. Scientific Sampling Program

We collected samples from the cave system, which included water, sediment, bacteria, bacteriophages, eDNA, and geological analysis (fossils and speleothems). Environmental parameters like salinity, pH, and temperature were recorded to assess the cave system's health and biodiversity.

3. Community Engagement

We organised two community events in Lasongko village to share our expedition's findings and highlight the significance of the Laulawi Aquifer and the geological importance of Muna Island as a whole. Presentations in Indonesian were delivered by both scientists and cave explorers. The team also broadcasted three live sessions to classrooms across the globe, engaging students with real-time exploration insights and scientific discussions. We conducted a quantitative ethnographic survey in Lasongko village with a purposive sample of participants to gain insights into local relationships with and needs surrounding water.

4. Challenges

- *Logistical Difficulties:* Operating in a remote region with limited access to medical facilities, required extensive planning for emergency evacuation and medical support.
- *Risk Management:* We faced risks while navigating both wet and dry cave systems. A detailed daily diving protocol and a medical protocol were established in collaboration with SOS International, DAN Europe, and other partners.

- *Medical Issues:* Ear infections, UTI's, fevers, common colds affected the team.
- *Technical Issues:* Cave diving and scientific sampling were complicated by equipment failures, but thorough preparation allowed us to manage these challenges effectively.

Pre-dive checklists in the Laulawi entrance: (L-R) Maria Bollerup, Rannvá Jørmundsson, Kirstine Toxværd (Tom Lindboe 2024)

Rasmus Dysted exploring inside Laulawi (Alex Dawson 2024)

Sediment sampling in the dry caves: (L-R) Juswono, Ambu, (Tom Lindboe 2024)

Head of Cartography David Mayor (R) planning a mapping meeting with Ambu (L) and Arie (middle) (Tom Lindboe 2024)

TEAM

Expedition Buteng members in attendance on the first day outside the Laulawi cave entrance;
(L-R) Front row: Kirstine Toxværd, Arie Sapputra, Bidu, Niar, Ida Asyari Utomo, Kirana Raditya, David Mayor, Audita Harsono, Tonny Budianto, (L-R) Second row: Juswono Budisetiawan, Harits Maulana, Aki, Ambu Hamrullah, Caca, Alex Dawson, Magnus Määttä, Tamara May, Ahmad "Madha" Ramadhan, Rasmus Dysted, Robin Cuesta, Kharisma, (L-R) Top row: Maria Bollerup, Rannvá Jørmundsson, Natalie Gibb, Denéa Buckingham (Tom Lindboe 2024)

Our team comprised 28 members including divers, cavers, scientists, storytellers, and support personnel from 8 countries.

Key Members and Leadership:

- Maria Bollerup; Project Lead, Nixie Expeditions Co-Founder and Scientific Diver, Denmark.
- Rannvá Jørmundsson; Project Lead, Nixie Expeditions Co-Founder and Scientific Diver, Faroe Islands.
- Robin Cuesta; Indonesian Partnerships, Local Logistics and Push Diver, France.
- Rasmus Dysted; In-field Expedition Leader and Push Diver, Denmark.

Science Team:

- Prof. Dr. Eko Haryono; Science Lead, Faculty of Geology UGM, Indonesia.
- Dr. Kirstine Toxværd; Science Coordinator, Faculty of Biology, Copenhagen University, Denmark.

- Dr. Abdul Rahman Siregar; Faculty of Biology, UGM, Indonesia.
- PhD. candidate Rakhmat Dwi Putra; Faculty of Geography, UGM, Indonesia.
- MSc. Ahmad Cahyadi; Hydrology? UGM, Indonesia.
- MSc. student Ida Asyari Utomo; Faculty of Biology UGM, Indonesia.

Remote Scientific Support:

- Dr. Dwi Sendi Priyono; Faculty of Biology UGM, Indonesia.
- Dr. Nastiti Wijayanti; Faculty of Biology UGM, Indonesia.
- Dr. Jill Heinerth; Underwater Scientific Sampling, Victoria University, Canada.
- Dr. Thomas Sicheritz-Pontén, Globe Institute, Copenhagen University, Denmark.
- PhD. Bent Petersen, Computational Biodiscovery Group, Globe Institute, Denmark.
- MSc. Daniel Ortega, Marine Biology, Marine Genome Project, USA.

Cave Diving Team:

- Natalie Gibb; Dive Team Lead and Push Diver, USA.
- Alex Dawson; Underwater Photographer and Videographer, Sweden.
- Magnus Määttä; Underwater Lighting Assistant, Sweden.
- David Mayor: Underwater Cave Survey Lead, France.
- Tamara May; Emergency Procedures and Underwater Survey, Australia.
- Arie Saputra; Underwater Survey, Indonesia.
- Audita Harsono; Underwater Survey, Indonesia.

Dry Caving Team:

- MSc. Juswono Budisetiawan; Dry Cave Team Lead, Faculty of Biology UGM, Indonesia.
- Ambu Hamrullah; Archeology, Faculty of Cultural Sciences from Universitas Hasannudin, Makassar, Indonesia.
- Kirana Raditya; Faculty of Forestry, UGM, Indonesia.
- Tonny Budianto; Geographical Information Systems (GIS) Specialist, University of Palembang, Indonesia.
- Abdul Choliq Kharisma Yuda; Faculty of Political Science, University PGRI ROnggolawe Tuban, member of FINSPAC HIKESPI and Rescuer at BPBD, Indonesia.
- Ahmad “Madha” Ramadhan; Marine Archeology, Faculty of Fisheries & Marine Sciences, UGM, Indonesia.
- BSc. student Harits Maulana; Faculty of Biology, UGM, Indonesia.

Media, Cultural Heritage, and Support Team:

- MPhil. Denéa S. Buckingham; Cultural Studies and Digital Communications, Faculty of Archaeology and Heritage Studies, University of Cambridge, Australia.
- Tom Lindboe; Photography and Videography, Denmark.
- Caca; Lead of the Dive Support Team, Indonesia.
- Bidu; Dive Support Team, Indonesia.
- Aki; Dive Support Team, Indonesia.
- Niar; Dive Support Team, Indonesia.

Sponsors:

Rolex and the Perpetual Planet Initiative, MAC3 Impact Philanthropies, Wings World Quest

Supporters & Partners:

MAC3 Impact Philanthropies, Fourth Element, Halcyon, Seacraft, DAN Europe, DAN World, Divesoft, The Explorers Club, Kadena Glamping & Dive Resort, Sulawesi Dive Trek, Exploring By The Seat of Your Pants, Copenhagen Global, Danish Defence, Xdeep, Big Blue Europe, Shearwater Research, Dive Signs, Copenhagen University, Marine Genome Project, and Phreatic.org

IMAGERY

Camaraderie underground; (L-R) Kirana Raditya, Madha Ramadhan, Kharisma Yuda, Kirstine Toxværd (Tom Lindboe 2024)

A filter retains traces of genetic material from water samples taken inside Laulawi (Tom Lindboe 2024)

Diver Rasmus Dysted exploring the expansive cave formations inside Laulawi (Alex Dawson 2024)

A fossilised giant clam, one of many indications of Laulawi as a prehistoric coral reef (Alex Dawson 2024)

Rannvá Jørmundsson carefully navigating a shallow section of *The River* part of the Laulawi cave system (Alex Dawson 2024)

Professor Eko Haryono conducting a survey of the island's varying elevations to determine when it was last under water (Tom Lindboe 2024)

Dr. Abdul Rahman Siregar uses a MicroPCR to conduct DNA analysis in the field looking for novel vira in the waters of Laulawi (Tom Lindboe 2024)

Hauling dive gear into La Cimindaka cave (Tom Lindboe 2024)

Kharisma Yuda surveying to map a new cave near Laulawi (Tom Lindboe 2024)

Exploring and mapping inside Laulawi (Alex Dawson 2024)

Fragile “soda stream” calcium formations (Alex Dawson 2024)

Science coordinator Kirstine Toxværd and cultural heritage and media coordinator Denéa Buckingham spending time with new friends in Walengkabola village (Tom Lindboe 2024)

Audita Harsono and Robin Cueta presenting the expedition’s goals and activities in Lasongko village (Tom Lindboe 2024)

EXTENDED EXPEDITION REPORT

Methodologies

Biology Studies: Analysis of eDNA samples in water and sediment to study cave biodiversity: filtration, DNA extraction, polymerase chain reaction (PCR), sequencing, bioinformatics analysis, and assessment of species diversity and abundance. Analysis of microbial DNA samples in sediment to study cave biodiversity and potential medical applications: as above, plus bacterial culturing to isolate and study specific microorganisms for medical research.

Geography/Hydrology Studies: Field measurement of hydrogeochemical parameters (such as pH, temperature, conductivity) and water flow rates to assess the cave system's water dynamics and how they influence the ecosystem. Measurement of salinity gradients in different parts of the cave system to trace water movement and understand the mixing of fresh and saline waters, which may indicate the health of the aquifer and possible pollution sources. Water quality analysis, including testing for contaminants, which is crucial for the preservation of the cave's ecosystem and surrounding water resources.

Geology Studies: Dating of geological samples to characterize the age and development of the cave system and surrounding area. This helps to reconstruct past environments and understand the geological processes at play. Satellite imagery and speleological surveys were used to analyze large-scale geological formations, including fault lines, sinkholes, and cave networks. Investigation into the genesis of cenotes and hypogenic caves to understand their formation processes, which can shed light on the region's geological history and aid in cave conservation efforts.

Pre-Expedition Preparation and Co-ordinations:

Science team:
The field sampling logistics was meticulously coordinated by Science Coordinator Dr. Kirstine Toxværd. We carefully planned sampling methods, and they were tried and tested prior to the expedition to ensure all equipment and materials were fully prepared for data collection and processing. Given the remote nature of the cave system, team safety was a top priority. Clear protocols, well-prepared and clearly labeled equipment minimized the risk of errors and confusion. Critical to the success of the expedition, was avoiding the need for re-sampling, preventing protocol ambiguities, and ensuring samples remained uncontaminated.

Cave Diving Team:

To prepare for the expedition, the majority of the cave diving team underwent specialized training in Mexico, within cave environments similar to those of the expedition. The training included:

- Rebreather Crossover Training:

Team members received training on the KISS Sidewinder rebreather due to the remote nature of the expedition site. This training minimized the need for multiple types of spare rebreather equipment and enabled team members to navigate the cave's most remote and narrow passages efficiently.

- Technical DPV Training:

To enhance safety, Diver Propulsion Vehicles (DPVs) were incorporated to transport divers through the cave tunnels, significantly reducing swim time and lowering the risk of decompression sickness—the primary threat to the team. Team members were trained on Seacraft DPVs to become familiar with their operation, emergency procedures, and protocols for transporting scientific samples safely.

- Cave Survey and Mapping:

Accurate mapping of the cave system and its water reserves was essential. Mapping Team Lead David Mayor conducted specialized training in underwater cave surveys, ensuring his team was well-prepared for this critical task and aware of the associated risks.

- Cave science stations:

The team installed and conducted sample stations throughout the cave to retrieve previously unreachable data samples.

- Cave Survey:

As part of the studies conducted by Prof. Dr. Eko Haryono, an estimation of the body of water was requested. To deliver this, the passages in the cave were measured.

Underwater mapping (cartography) was conducted using specific protocols developed specifically for this environment. The limited visibility, the wet environment and the inability to use classic dry mapping equipment led divers to implement new techniques to produce an accurate and scientifically usable survey and map.

The initial guideline survey was done using a “Mnemo”; a specialized underwater survey device, developed to produce a line survey.

Conducting LRUD (Left/Right/Up/Down) mapping and 3D modelling of the underwater cave systems to create detailed models of tunnels for determining the approximate size of the aquifer and the volume of water.

- Dry Cave Survey:
Most significant caves have been surveyed and mapped using standard UIS (International Union of Speleology) survey protocols.
Cave surveying and mapping is scientifically relevant for several purposes:

- The overall shape of the cave and specific passages provide valuable information to determine the morpho chronology and speleogenesis process of cave formation.

- The cave distribution helps karst scientists to determine the main drivers of cave formations across time and predict cave locations for future exploration.

- The cave size is useful to determine the water catchment area and analyse possible routes of contaminants into the cave system. This information is required for conservation and protection purposes.

Equipment

Cave surveying has been conducted using specialised equipment :
- High-precision GNSS System to plot the entry of caves.
- Laser pointer Leica Disto D510 to measure distance between measuring stations and also - distance from measuring station to floor, ceiling and right and left walls.
- Suunto tandem 360PC to measure azimuth and inclination.
- Sketch book to sketch details about cave passages.
- Standard single rope techniques to progress through the dry passages.

Accuracy

The survey has been done according to the UIS grade standards achieving a grade of 5D.

Grade 5 relates to the accuracy of cave line survey where horizontal and vertical angles are measured to ±1°; distances and should be observed and recorded to the nearest centimetre and station positions identified to less than 10cm.

Class D refers to the measurements of detail being made at survey stations and wherever else needed to show significant changes in passage dimensions.

Cultural Heritage Studies

Based on an ethnographic mixed-methods research protocol including quantitative surveying and qualitative semi-structured interviewing, our cultural heritage research sought to elucidate the relationships of local communities with water, caves, and cave aquifers. The purpose of this research was to take the initial steps towards articulating the region's cultural-geological connections which forms an integral aspect of a UNESCO Geopark application. Additionally, our quantitative research aimed to develop insights into the local uses of water and needs around water which are important to informing any future development efforts of the region's water sources.

- Completed a quantitative ethnographic survey of 69 community members from Lasongko Village.
- Conducted qualitative, semi-structured interviews with 4 participants from Walengkabola Village (Muna Regency).
- Engaged local communities through village-wide events to share expedition findings and highlight Geopark benefits.

KEY FINDINGS AND RESULTS

Mapping and Surveying:

We mapped and explored 5.2 kilometers of the flooded Laulawi cave system, making it currently the longest underwater cave system in Southeast Asia.

We documented 22 dry caves, and fully mapped five.

Biological Research:

eDNA Analysis: Low eDNA concentrations suggest extreme environmental conditions in the cave (e.g., low oxygen levels, no sunlight).

Microbial Diversity: Bacterial DNA was successfully extracted, with cultures set to be sequenced in 2025.

Hydrological Research:

We discovered interaction between fresh groundwater and saline water, linking the Kampolele spring with the cave system.

Geological Research:

We identified six terraces marking uplift events and uncovered fault-controlled hypogenic features in the Laulawi Cave system.

Cultural Study:

Muna communities showed a strong cultural connection to the caves, highlighting their importance in local folklore and daily life. Buton communities showed a strong reliance on caves for practical use and daily needs.

Community Engagement:

The expedition engaged the local Muna community through two key events:

Knowledge Sharing: The team explained the expedition's goals and shared the significance of the Laulawi Aquifer and caves.

UNESCO Geopark Awareness: The project added information to, and encouraged additional enthusiasm for, exploring a UNESCO Geopark application.

In addition, the expedition utilised live broadcast sessions to engage classrooms worldwide, increasing awareness and inspiring future generations of explorers and scientists

POST-EXPEDITION

As a direct result of the expedition or as an extension of the activities during the expedition:

- UGM & KU: Meeting in Copenhagen, Denmark between professors from the University of Copenhagen and Universitas Gadjah Mada. Discussing the science outcomes from the expedition, and agreeing on future collaboration between the faculties/countries
- Science Sorø: 3 fold livecast into Gymnasiums across Denmark. Engaging young adults (17-21 year), in exploration, field research and bio-engineering through super computers
- Public presentations will continue throughout 2025 in various venues, encouraging interest for the subject of aquifer conservation and exploration.
- Podcasts are scheduled throughout 2025
- Scientific papers have been agreed between the team members from UGM
- Archaeological map of a significant Muna burial site with connections to caves in digitisation progress
- Quantitative survey results for use by the local community and in future heritage research
- Three short videos about the importance of extreme exploration, the expedition, and Nixie Expeditions
- Oceanographic magazine article
- Articles in dive-specific magazines
- The Explorers Journal (in discussion)
- Further Expedition commitments

CONCLUSION

Expedition Buteng made significant contributions to understanding the Laulawi Aquifer and its surrounding cave systems, marking a milestone in tropical karst science.

The expedition succeeded in:

Mapping unexplored caves and aquifers, contributing vital data to the scientific community.

Collaborating with UGM to advance knowledge on cave biodiversity, hydrology, and geology.

Engaging with local communities to support conservation and raise awareness about the importance of Muna Island's geography, hydrology, and cultural relationships with both in aid of a future UNESCO Geopark application.

These accomplishments highlight the vital connection between scientific exploration, environmental conservation, and community empowerment.

A rare cave formation called *The Table* inside the Laulawi aquifer (Alex Dawson 2024)

ACKNOWLEDGEMENTS

We express our deepest gratitude to our sponsors: Rolex's Perpetual Planet Initiative and MAC3, for their generous support. We also thank Gadjah Mada University for their collaboration and the Muna and Buton communities of Lasongko Village and Walengkabola Village for their hospitality and commitment to the preservation of their natural heritage.

Additional thanks to the Marine Genome Project for sharing their sampling protocols and to all partners involved in making this expedition a success.