CINDAQ
Surfacing Vital Knowledge

2023

CINDAQ 2023 Annual Report

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Facilitate **research**, promote **education** and support the **conservation**
of the natural and cultural resources associated
with the cenotes and underground rivers of Quintana Roo, México

Explore

CINDAQ Annual Report for 2023

Content

EDITORIAL

Surfacing vital knowledge

Leveraging **exploration** as a tool to generate **usable data** to better understand and protect our **aquifer**

With **over 25 years dedicated to the exploration and research of the Ox Bel Ha system**, we take pride in its transformation from uncharted territory in 1997 to the second longest cave on Earth. Technological advancements have significantly enhanced our exploration efforts, leading to a shift in focus from solely exploration to generating a myriad of usable data. As we extend our methodologies to other caves in the region, patterns emerge, emphasizing the crucial role of flooded caves in connecting the area's natural and cultural heritage. The insights gained emphasize the pressing need to **establish a scientific understanding of our aquifer through collaborative efforts**, steering the region toward a sustainable future amidst various threats.

In 2023, despite ongoing projects in the region, our focus on the Ox Bel Ha cave system intensified due to the escalating urbanization of Tulum and the development of the Tren Maya and Tulum International Airport. The cave's total surveyed length reached 496.8 km by year-end, reflecting its significance amid expanding urbanization. While boasting over 1,000 biological observations within Ox Bel Ha, we sadly report instances of marine plastics and sargassum seaweed infiltrating the cave in areas directly accessible from the Caribbean Sea.

Our exploration continued beneath the **Sian Ka'an Biosphere Reserve**, including a trip to Punta Pájaros, revealing strategic opportunities for access to remote areas. Collaborating with CONANP, we returned to Cenote Tuun Ja, achieving multiple objectives. We conducted a thorough resurvey of the **Crustacea** cave system, expanding its footprint by connecting it with two adjacent systems. Documentation efforts also focused on the rich diversity of achialine fauna thriving within Crustacea.

Collaborating with Dr. Luisa Falcón, we contributed to microbialite studies in **Bacalar**, fostering collaboration among researchers. Our involvement in aerial mapping of **Chichen Itza** and **Ek' Balam** showcased our technological capabilities outside the water. Preliminary findings from a virology study conducted in 2020 revealed significant metagenomic analysis, uncovering unique microbial populations beneath the Municipality of Tulum. The potential discovery of a new brittle star species in Ox Bel Ha highlighted our role in expanding knowledge of anchialine environments, Dr. Fernando Alvarez's ongoing investigation adds an important ecological dimension.

Improvements in our Geographic Information System (GIS) allowed us to model the halocline depth in Ox Bel Ha, create visualizations of observations, and explore ways to aid exploration efforts and enhance dive planning and safety. Participation in **UNESCO** meetings, including the First Intersectoral and Technical Meeting on Best Practices and Underwater Cultural Heritage in Cozumel, demonstrated our commitment to global collaboration. Attendance at the UNESCO statutory meetings in Paris, the ESRI Users Conference in San Diego, and visits to UC San Diego and the Scripps Oceanographic Institute provided valuable insights and facilitated discussions on data sharing and scientific diving programs.

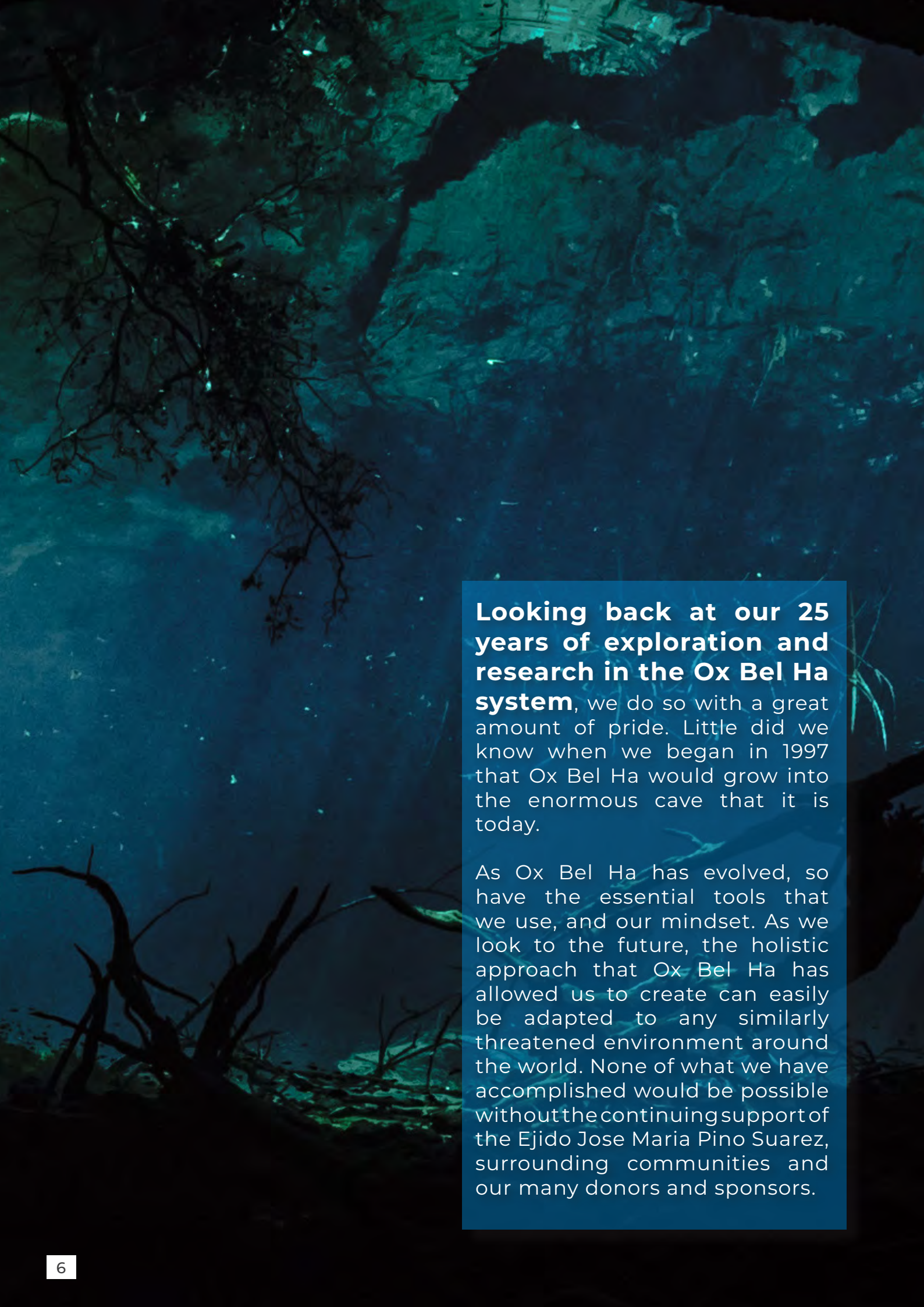
Public outreach efforts involved presentations at universities, conferences, and local communities. Our involvement in significant media productions, such as BBC's Planet Earth III: Freshwater and National Geographic's: The and Fall of the Maya, showcased global interest in the region and promoted conservation messages. In-house productions on the Bacalar Project, a testimonial for SUEX and a showreel for Nauticam highlighted our growing ability to document our work effectively.

We are grateful for the continued support that enables us to conduct this vital work.

2023

73,839 M RESURVEY
43,621 M EXPLORATION
117,460 M TOTAL

OX BEL HA:
25 YEARS OF EXPLORATION



Looking back at our 25 years of exploration and research in the Ox Bel Ha system, we do so with a great amount of pride. Little did we know when we began in 1997 that Ox Bel Ha would grow into the enormous cave that it is today.

As Ox Bel Ha has evolved, so have the essential tools that we use, and our mindset. As we look to the future, the holistic approach that Ox Bel Ha has allowed us to create can easily be adapted to any similarly threatened environment around the world. None of what we have accomplished would be possible without the continuing support of the Ejido Jose Maria Pino Suarez, surrounding communities and our many donors and sponsors.

OX BEL HA - 25 YEARS OF EXPLORATION (CONT.)

In 1997, Ox Bel Ha, as we know it today, did not exist. At that time, the Naranjal System had already been established as one of the larger systems in the Tulum area thanks to the efforts of Jim Coke and his team of divers. To the south of the Tulum beach, Gary and Kay Walten had just begun to explore the Yax Chen system. Between these two systems lay uncharted territory, and a significant opportunity. From 1997-2001 the Grupo de Exploración Ox Bel Ha (GEO) systematically explored this area by leapfrogging from one cenote to another, quickly establishing Ox Bel Ha as a very large and significant cave. Inspired by the work of Mike Madden and his team at Cenote Nohoch Nah Chich, jungle base camps were used to maximize our efforts and grow the system. From the early 2000's, **the Mexico Cave Exploration Project (MCEP), CINDAQ, and GEO** (Bil Phillips, Steve Bogaerts and Sabine Schnittger) continued with significant exploration efforts, with GEO continuing until Bil's untimely death in 2017. During this period, Ox Bel Ha grew significantly through original exploration of all teams and the connections to the Naranjal,

Chuup Ich and Yax Chen systems by Bil and Steve. At the close of 2023, we can report 496.8 km of survey, making it the second longest cave on earth, wet or dry.

SInce the mid 1990's we have witnessed steady improvements to the equipment that we depend on. From open circuit SCUBA, we have evolved to use passive semi closed circuit rebreathers (both backmounted and sidemounted). PSCRs give us longer bottom times, improve logistics and increase productivity on every single dive. The advent of lithium ion batteries and LED technology let our

lights burn longer and brighter, allowing us to see the cave much better than we could with the lead acid batteries and 35-50 watt halogen bulbs that we used in the beginning. Our use of SUEX scooters has increased our range significantly; we can visit all corners of this massive cave from cenotes that are more easily accessible. Our use of the Mnemo cave survey tool has also improved our efficiency and productivity as we resurvey every single meter of line within the cave. Additionally, the Mnemo lets us be more situationally aware in order to make a multitude of observations within the cave. When seen on a large scale, these observations begin to reveal patterns that then lead to questions and further scientific research.

As a result, **our mindset has evolved as well**. We are no longer satisfied with exploring just for the sake of exploration. While it is very important to register the extent of the caves of this region, what we had always overlooked was what was contained within them. Thanks to our concerted efforts to resurvey the cave, we now have observations of everything from navigation, to biology, to flow patterns, to paleontology and many others. With every new scientist that we work with, we become aware of one more thing to be observant of, and how almost all of these observations are tied together in a complex web of interrelationships.

Out of all of this has emerged a well documented workflow that can be applied to cave systems anywhere in the world. What has also become apparent is the need to apply it to as many caves in our region as possible as they become increasingly impacted by human activities. It is now impossible to ignore the fact that these caves, including Ox Bel Ha, are being negatively impacted by deforestation, urbanization and the resulting contamination of our freshwater supply. By having at least a baseline understanding of what lies beneath the ground and how it was originally found, we hope that our actions will help direct a sustainable future for all of us at the surface.

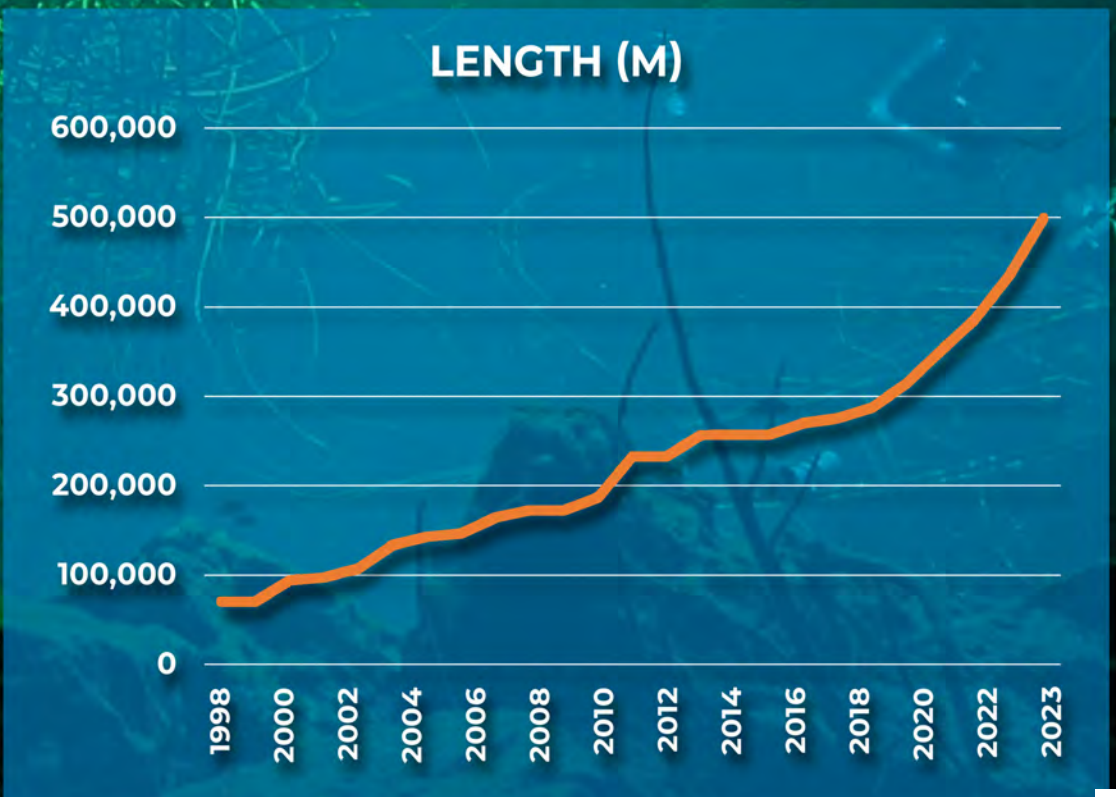
We are grateful to all of those of us that have supported us over the last 25 years, but in many ways **our greatest thanks is to the Ox Bel Ha system and the many lessons it has taught us**.

OX BEL HA

CONFIRMED DATA:	496,804 M
2023 RESURVEY:	47,434 M
2023 EXPLORATION:	26,136 M

CENOTES:	160+
SURFACE AREA:	69+ KM²
N-S DISTANCE:	12,000 M
E-W DISTANCE:	9,000 M
WIDEST PASSAGE:	120+ M
AVERAGE DEPTH:	12.8 M
DEEPEST DEPTH:	57.3 M
MAX. LOOP CLOSURE:	7,500 M

SURVEY STATIONS:	56,674
SECTIONS:	615
AVERAGE SHOT:	12.8 M
JUMPS:	2,500+
T INTERSECTIONS:	1,500+
ARROWS/MARKERS:	7,683



OX BEL HA - CINDAQ 2023

Ox Bel Ha's diversity and complexity creates **a mesmerizing array of sceneries** of interconnecting cave conduits peppered with over 160 cenotes, and three distinct vents that discharge freshwater into the Caribbean Sea.

It is home to a unique ecosystem that combines both fresh and saltwater environments. Saltwater is visible almost everywhere in the cave. The halocline (the interface between fresh and saltwater) can readily be found from a depth of 10-12 m near the beach line in Tulum and up to 20 m deep ten kilometers inland.

The relationship between these two environments creates **a multi-layer cave labyrinth of enormous proportion**. Ox Bel Ha is one of the most important hydrologic features of the vast Maya aquifer, feeding freshwater to the Quintana Roo coastline, and the wetlands of the Sian Ka'an Biosphere Reserve.

Within the Ox Bel Ha cave system are multi-directional groundwater movements with substantial tidal influence from the nearby Caribbean Sea.

2023 was another busy year for the CINDAQ team, and, despite our focus in other caves in the region, Ox Bel Ha is where the majority of our efforts were spent.

The rapid urban expansion of Tulum, coupled with the construction of the Tren Maya and the opening of the Tulum International Airport all make our work in this area even more pressing. Large parts of Ox Bel Ha are already beneath urbanized areas or areas slated to be developed, adding to **the sense of urgency for our continued efforts to map, document and better understand Ox Bel Ha**.

In 2023, we worked from 6 different cenote entrances: Cenote de La Familia, Cenote Odyssey, Cenote Tarpon, Cenote Perla, Cenote Wakax, and Cenote Gemini 2.

As a result, we were able to resurvey a total of 47,434 km of line and explore a total of 26,136 km of previously unknown passages. An additional ten cenote entrances were added to the system. As of the end of the year 2023, Ox Bel Ha can report that Ox Bel Ha has a total confirmed surveyed length of 496,804 m.

OX BEL HA - HALOCLINE STUDY

One of the many interesting features of the Yucatan caves is the halocline. This interface between the freshwater meteoric lens and the saltwater layer beneath creates the impression of a shimmering surface in the water column, and generates blurriness when disturbed due to the difference in the index of refraction between the two layers. While this makes for some stunning visual effects, it can also lead to a reduction of visibility during dives.

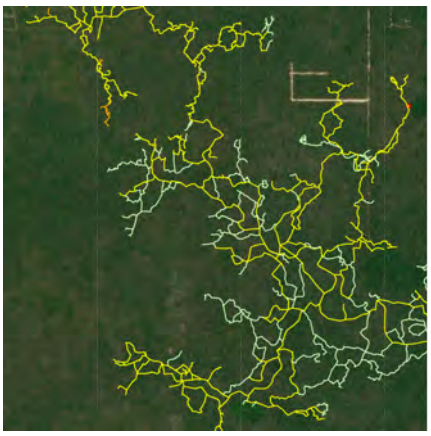
> Ox Bel Ha: a perfect system to experiment with a comments-based halocline study

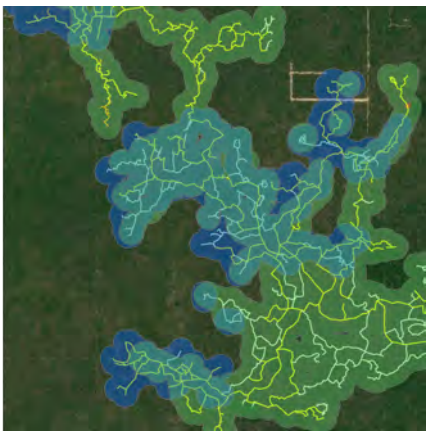
Since marine water is intruding from the coast via the karstic substrate, and the freshwater resulting from rains is thicker inland and pushing the saltwater down, the depth of the halocline at any given point of a cave will depend on the distance from the coast, but numerous other factors are also contributing. Several scientific models, like the Dupuit-Ghyben-Herzberg analysis, aim to calculate the halocline depth, taking into account hydraulic conductivity, which is the property of the porous substrate to let water through with more or less ease, as well as the freshwater recharge. This might be **simple enough in theory in a perfect sand body** with a known geometry, but is much **more difficult to calculate in the real world**.

Rainfall at the surface, porosity of the different geological layers, water flow and flow impediments, tunnel geometry, and underlying substrates are just a few of the features that will influence the real depth of the halocline in any point of the cave. Not only do the number of variables make it difficult to model accurately, but a high variability is likely to be observed from one area to another, one cave to another, and even from one tunnel to another in the same cave.

An alternative approach to estimate the depth of the halocline is to **obtain an observation-based approximation using diver comments** and choosing the coastal distance as the main parameter. If divers observe halocline depth in as many locations as possible in a cave, it should be possible to infer a mathematical relation that is based on actual field data and applicable over other points of the system.

Ox Bel Ha presents a perfect environment to experiment with this idea. It has been explored and studied for 25 years, and the CINDAQ team has had the unique opportunity to resurvey almost the entire cave with detailed, standardised comments since 2018, including the observed depth of the halocline at over 300 points. Furthermore, these 300 observations by CINDAQ divers cover a coastal distance that extends inland over 8 km. Moreover, these observations are evenly distributed over the entire system. The combination of diver comments and

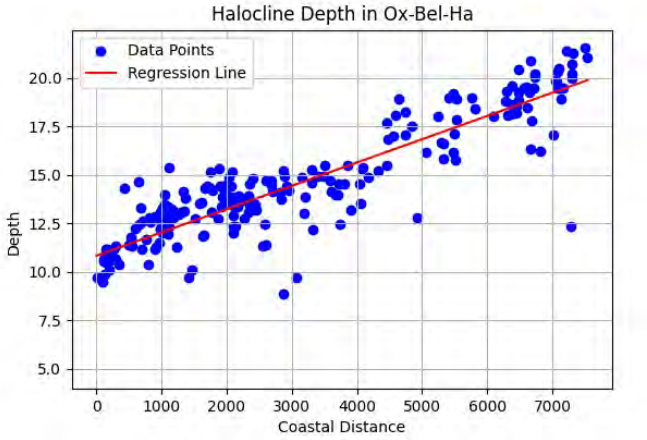




the use of a **Geographic Information System (GIS) for cave data analysis** makes it relatively easy to compute coastal distance not only for the 300 points with halocline observations, but also for all 56,000 stations currently in our survey.

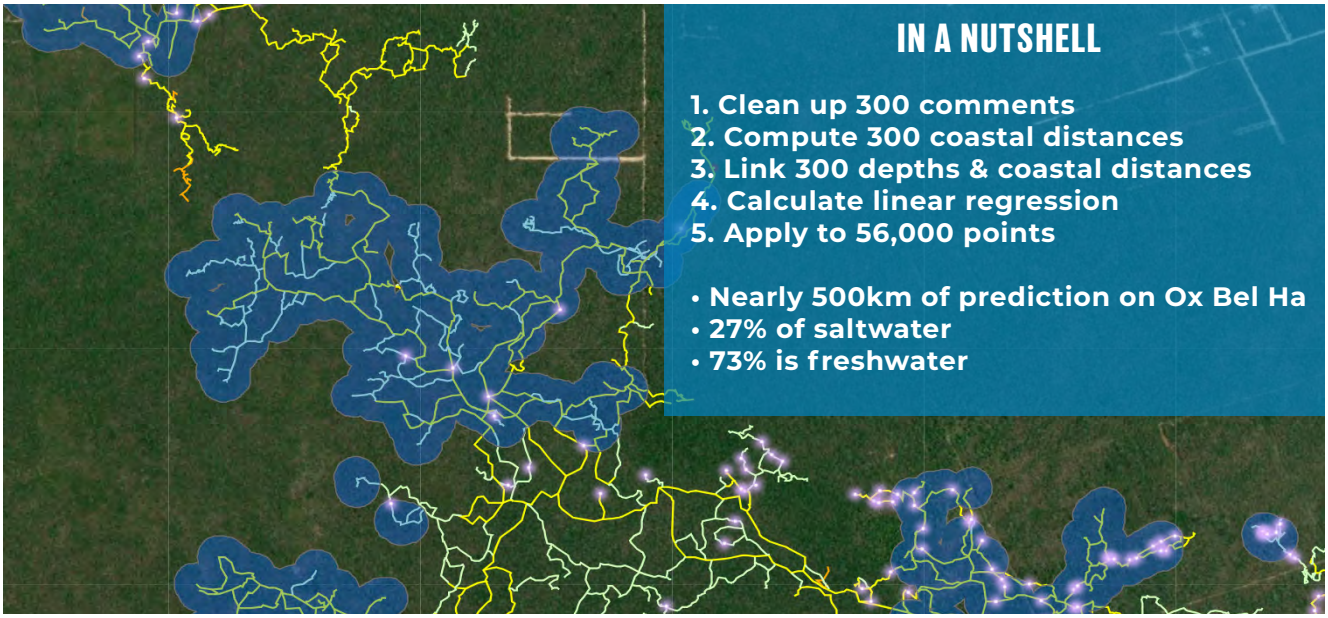
The method developed by CINDAQ consists of 4 main steps:
1. Cleaning up the comments on all 300 halocline observations in Ox Bel Ha
2. Using a GIS system to calculate the coastal distance of the 300 points
3. Generating a table with the depth and coastal distance of the 300 halocline observations
4. Using statistical computing software to obtain a linear regression of the halocline depth as a function of the coastal distance.

The resulting regression was surprisingly good, with a Pearson correlation coefficient of nearly 0.87. The next step was then to compute coastal distance for all 56,000 points in Ox Bel Ha, and apply the linear regression equation to this coastal distance to estimate the theoretical halocline depth at that point. If the station was deeper than this calculated value, it was likely in saltwater, and in fresh water otherwise.



This allowed the CINDAQ team to **generate a visual representation of the probable distribution of freshwater and saltwater** over the nearly 500 km system. Based on this, we estimate that **27% of Ox Bel Ha is saltwater while 73% is freshwater**.

Predicting reality based on concrete observations and one main parameter rather than a general perfect-world equation based on multiple, hard-to-measure parameters might not appear as the most accurate method at first sight. However, random testing throughout dozens of points in the system have shown a surprisingly high level of predictive accuracy. This can be a very valuable tool to quickly relate the fresh/saline property of water with other observations, like biology, ochre, flow, or any other geological, hydrological, virological features throughoutOx Bel Ha. Finally, an exciting perspective is to replicate the same method in other cave systems in our region, allowing us to refine it while **improving our understanding of the aquifers**, and to publish both our findings and a general method within the next year.



SIAN KA'AN - PUNTA PAJAROS

Since 2006, CINDAQ has been **exploring, documenting and helping to better understand the network of flooded caves beneath the Sian Ka'an Biosphere Reserve**. Our core objective is simple: seek ways in which to overcome the significant logistical challenges, and continue to expand our areas of exploration. We now have several 'windows' into the aquifer of Sian Ka'an that stretch from the northern border down into Punta Pájaros.

Each area provides us with **another piece of a complex and intriguing puzzle**. Put together, these pieces helped us begin to define what could potentially be an enormous cave system in the northern half of the reserve. The remoteness makes the diving logistics extremely challenging, but we feel that our team, our resources and our experience will overcome these challenges and reveal what lies beneath Sian Ka'an.

KEY FACTS ABOUT THE SIAN KA'AN BIOSPHERE RESERVE

- LOCATED IN Q. ROO, MEXICO, SOUTH OF TULUM.
- UNESCO WORLD HERITAGE SITE SINCE 1987.
- RECOGNIZED AS A WETLAND OF INTERNATIONAL IMPORTANCE UNDER THE RAMSAR CONVENTION.
- COVERS OVER 500,000 HECTARES OF MARINE, COASTAL, & TERRESTRIAL ECOSYSTEMS.
- 1/3 OF THE LAND MASS IS MANGROVE: OF VITAL IMPORTANCE FOR THE REPRODUCTION OF CERTAIN MARINE SPECIES BUT ALSO KEY IN TRAPPING SEDIMENT.

THE SIAN KA'AN BIOSPHERE RESERVE IS HOME TO:

- 120 TREES AND SHRUBS SPECIES
- 1,200 PLANT SPECIES
- 339 BIRD SPECIES
- 52 FISH SPECIES
- 42 AMPHIBIAN & REPTILE SPECIES
- 103 MAMMAL SPECIES INCL. JAGUAR & TAPIR
- 23 MAYA ARCHAEOLOGICAL SITES

From August 23rd to September 1st, 2023, **members of CINDAQ**, in accordance with the permit issued by CONANP on the 28th of August, 2023, and at the invitation of the Casa Blanca Fishing Lodge, **flew to the remote island of Punta Pájaros and the Bahía de Ascensión to investigate the presence of caves and the potential for their exploration**.

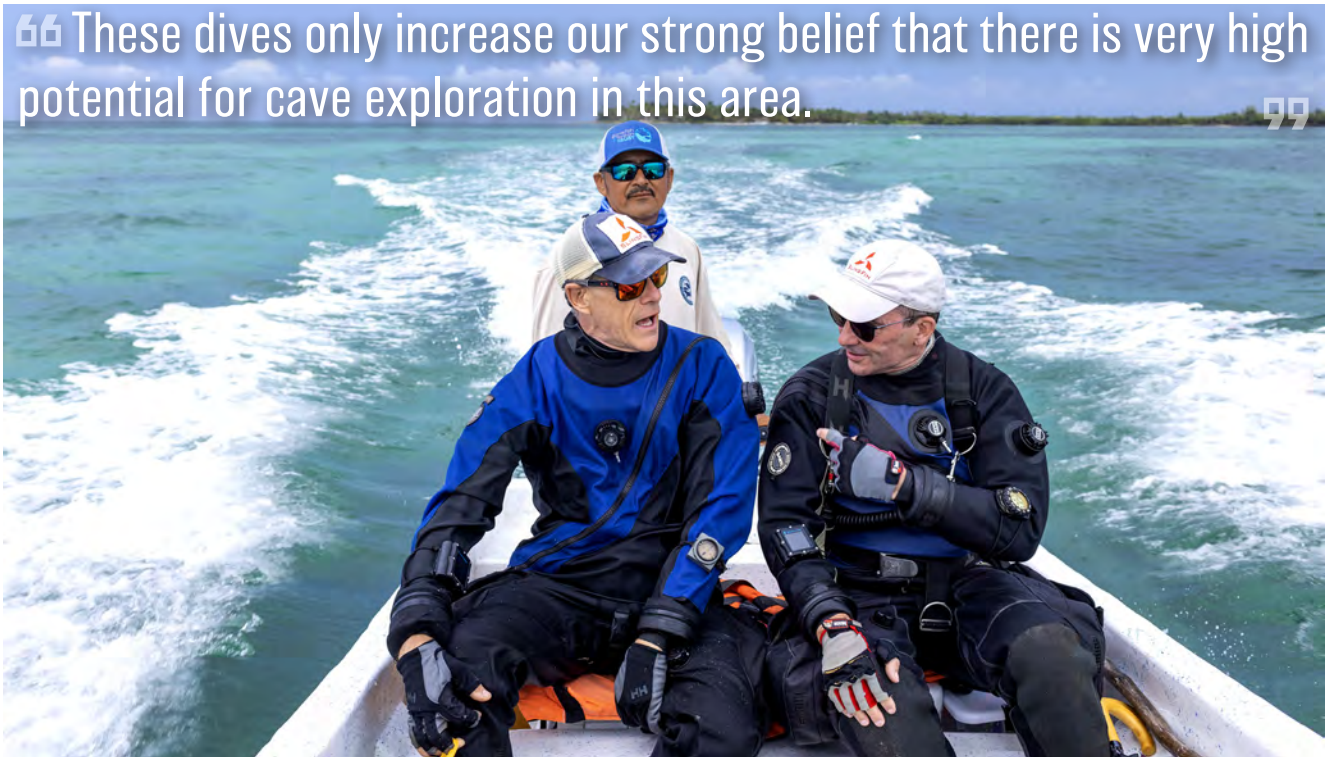
In an effort to better understand the general area of Punta Pájaros, we spent 2 days being shown around the island by the staff of Casa Blanca.

This included visits to Laguna Verde, the Tupac Archaeological site, the Chac Mool archaeological site, Cenote Casa Blanca, Entrada Hualaxtoc and Punta Sacrificios.

At each location we did our best to **assess and document** them **with drones and surface cameras** with the help of our friend **Mauricio Ramos**. We also provided a presentation to assembled guests and staff about CINDAQ and our activities
.

Punta Pájaros is in a strategically important area of the reserve, and with its world class logistics and infrastructure, it could play a significant role in helping our team access the most inaccessible areas by boat and helicopter. During our trip, two dives were undertaken in Entrada Hualaxtoc and in Cenote Casa Blanca. What we saw on these dives only increases our strong belief that there is very high potential for cave exploration in this area.

For more info: *cindaq.org/pajaros_airtour*



SIAN KA'AN - MUYIL-XAMACH & TUUN JA

On the 31st of May, 2023, members of CINDAQ, and the Comisión Nacional De Áreas Naturales Protegidas (CONANP) in accordance with permit F00.9.RBSK/516/2-23 (issued on the 23rd of May, 2023), flew by helicopter from Puerto Morelos to the Zona Nucleo of the Sian Ka'an Biosphere Reserve with **2 main areas of interest: Cenote Tuun Ja & the Muyil-Xamach forest fire site.**

We first landed at the Muyil-Xamach site with the following four objectives:

- **Land at the Muyil-Xamach forest fire site** to fly a DroneDeploy mapping mission with our Mavic 2S drone for comparison with previous assessments from 2021/2022
- **Document the area** with high resolution photos and videos with our Mavic 3 Cine drone and Sony A7S iii cameras
- **Facilitate CONANP personnel** to conduct their own assessments
- **Document CONANP personnel** as they conducted their assessments

We were able to complete all of our objectives. We now have three high resolution orthophotos of the site taken annually from 2021-2023. This information helps CONANP better understand forest regeneration when combined with their own transects over time.

THE SIAN KA'AN PROJECT SO FAR

- 4 HELICOPTER FLIGHTS INTO THE ZONA NUCLEO
- FOREST FIRE ASSESSMENT USING DRONES
- TWO EXPLORATORY DIVES IN CENOTE TUUN JA
- 1,315 M OF PRELIMINARY EXPLORATION
- BASE CAMP PREPARATIONS FOR 2024

We then proceeded to Cenote Tuun Ja with the following objectives:

- Retrieve and replace the three **camera traps** placed by CONANP in March, 2022;
- Test the **Starlink Internet System** and Inmarsat Satellite Phone;
- Interview the Director and Subdirector of the Reserve;
- Retest our **water filtration system** that makes the cenote water potable;
- Test the use of Ecoflow batteries to boil water for dehydrated meals;
- Further look at and discuss where a basecamp could be placed with the Director and Subdirector of the Reserve;
- Facilitate CONANP personnel to conduct their own assessments.

All objectives at Tuun Ja were completed.

The camera traps were retrieved and the results of one year of documentation indicate that there is an amazing amount of biodiversity present in the area, from apex predators on down.

Both the Starlink system and Inmarsat satellite phone performed flawlessly, ensuring that on future projects we will have effective communication, thus increasing our safety and ability to immediately communicate with all stakeholders.

We were able to quickly boil filtered cenote water and reconstitute dehydrated meals provided by Good To-Go.

The Ecoflow battery was able to power up all of these systems without issue. Our goal is to do everything possible to eliminate the risk of forest fires in our future basecamps. With Ecoflow we will be able to eliminate the risk by not having open flames for cooking. **We appreciate the support we have received from Ecoflow and Good To-Go**.

As we look forward to 2024, we project that we will initiate the first of what we hope to be many basecamp expeditions in this exciting area.

> “An amazing amount of biodiversity present in the area, from apex predators on down”

SISTEMA CRUSTACEA

While the Puerto Morelos area is usually associated with more vertical, sinkhole-like caves like Zapote, Siete Bocas or Fatima, Sistema Crustacea offers the more "classical" topography of a complex horizontal tunnel network typical of the cave systems found further south.

However, most similarities end there. Quintana Roo caves are known for their incredible visibility, yet **Crustacea features more sections with haloclines, tannic sections, hydrogen sulfide and bacterial growth** than transparent crystal-clear water. Typically, the flow in the caves of the region tends to be rather low, but in Crustacea, the confluence of several underground rivers creates substantial flow accelerating as they near the ocean vent. The multiple layers of the cave are linked with long vertical shafts which are reminiscent of European caves. Tunnels of various depths are intertwined in a three-dimensional maze, and to make matters more interesting, the water seems to dissolve nylon lines at a rate much higher than anywhere else in the region, requiring numerous line repairs and replacements.

The fauna in the system is also quite extraordinary, with an extremely high concentration of shrimp, to an extent that can lead to never-seen-before "shrimp-

whiteouts", as well as a mind-boggling number of remipedes, especially along the line dubbed Remipedia-City by Marike Jasper and the original explorers. The first anchialine gastropod in a Yucatan cenote, Teinostoma Brankovitsi, was also described in this cave system by Fernando Rubio et al. in 2012.

Ever since a BBC media project brought the CINDAQ team to Crustacea in 2022 to film the remipedes, we had been wanting to go back, resurvey all existing lines, document the cave as well as its features and inhabitants, and possibly find some new exploration. Starting on August 1st, and entering from a cenote very close to the beach with lines laid in 2001 by Dan Lins and Sam Meacham, we progressively resurveyed the entire cave in 26 days of diving and 33 dives. While the Quintana Roo Speleological Survey (QRSS) reported

KEY FIGURES

- **Resurvey of existing lines: 9,984 m**
- **2023 CINDAQ exploration: 13,199 m**
- **Confirmed length: 23,183 m**

4,879 m of passages as of 2012, we found 8,236 m of previously explored tunnels. The original exploration in 2001 by Marike Jasper, Steve Gerrard, Kate Lewis, Jeronimo Aviles as well as Bil Phillips, Sam Meacham, Steve Bogaerts and Mike Madden from 2001 to 2003, and Dan Lins from 2001 to 2008 had been extended upon by various divers, including but not limited to the biologist Thomas M. Iliffe in the north-western side of Crustacea (2012-2018), Rogelio Maier, Alejandro Reato, Jeronimo Aviles and Vincente Fito in the region bordering the ocean vent (2012-2017), Robbie Schmittner (2019-2023), Skanda Cophield and Philip Lehmann (2023).

A complex, multi-layered cave such as this one, where the water is often milky, and what appears to be a major tunnel often turns out to be a solid wall when observed closer, and vice-versa, is **quite challenging to figure out and explore**. However, once all of the original lines were systematically resurveyed, several interesting properties of the system became clear to us. First, there seemed to be a solid, non-passable geological core around which the system was wrapped in a moon-crescent shape with no loop closure on the northwestern side. Secondly, there were at least two different major water flows coming from the north and the west before joining forces towards the main beach vent on the coast. Finally, there seemed to exist numerous smaller tunnels underneath the beach area, with tons of marine debris including the **intrusion of Sargassum seaweed over 400 m into the cave**.

Working counter-clockwise past cenote Marike, we found an interesting layered section with a solid upper level at 19 m, and a 23 m-deep sublevel with flowstone walls and numerous decorations. 3 km of exploration eventually lead to the closing of the loop around the solid core into the Thomas Iliffe lines northwest of cenote Crustacea. The two major, distinct flows from north and west lead to two more exploration zones of 3km each, and to the connection to both Sistema Tumben Kuxtal and Sistema Chico Springs through massive tunnels and a stunning diversity of different cave environments, from wide salt water passage to big break-down areas with thick sediment layers and shallower, heavily decorated rooms. Another 3 km of exploration was made closer to the beach, including the discovery of a huge chamber, with an impressive length of 250 m and width of 50 m, leading from cenote Mysid to a smaller one close to the coast.

It is a pleasure to dive what is shaping up to be the 11th biggest system in the region, and certainly the biggest one on the coast North of Playa del Carmen. The very different nature of the cave, while offering some challenges that are uncommon further south, has made for an interesting adventure for us, one that we are looking forward to continuing working on in 2024.

KNOWN EXPLORERS

(to the best of our knowledge)

- Redondo, Jasper, Gerrard, Lewis, Aviles, Madden, Yager, Phillips, Meacham, Bogaerts, Lins, Granucci, Curiel: 2000-2009
- Mier, Reato: 2012
- Cucchiara, Biroli, Morales, Aviles, Fito: 2012-2017
- Iliffe: 2012-2018
- GAM: 2019
- Schmittner, Cophield, Lehmann: 2023
- CINDAQ Team: 2023

BACALAR

From May 1-5, 2023, CINDAQ assisted Dr. Luisa Falcón (Senior Researcher of Bacterial Ecology, Institute of Ecology, UNAM, Mérida) in her ongoing studies of microbialite communities in Cenote Azul located in the town of Bacalar.

Bacalar is located just north of the Mexico/ Belize border in southern Quintana Roo, and is the gateway to Laguna Bacalar. The laguna is a narrow body of freshwater that extends 42 km from north to south. While Cenote Azul is one of five reported cenotes in this area, it appears to be the only one not directly within, or connected to, the laguna. This is surprising as it is only meters away from the lake's shore.

This project provided an opportunity to bring together researchers from Mexico, Canada and the United States representing six academic institutions (UNAM Merida, CINVESTAV, ECOSUR, Tecnológico de Chetumal, McMaster University, The University of North Carolina) in the hopes of fostering closer working relationships

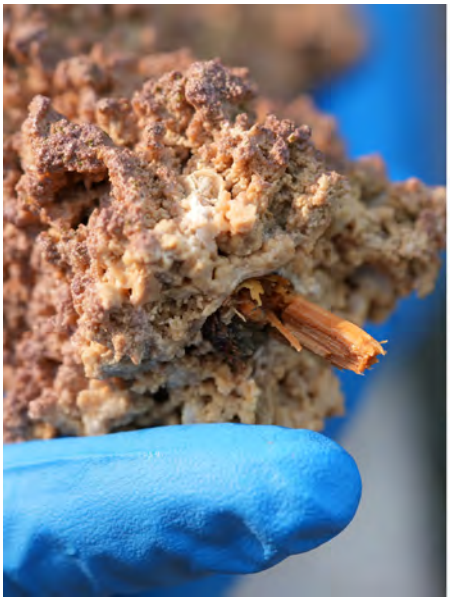
KEY FACTS ABOUT THE BACALAR MICROBIALITE PROJECT

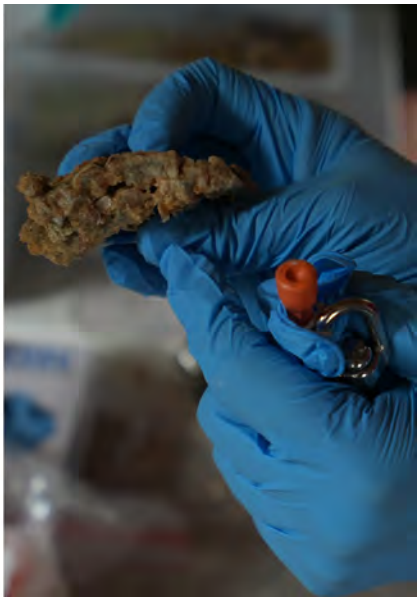
- 5 WATER SAMPLES COLLECTED
- 10 MICROBIALITES SAMPLES COLLECTED
- 5 PHOTOGRAMMETRY MODELS
- 9 DIVES BY 3 DIFFERENT TEAMS
- 500+ GB OF MEDIA (8:30 HOURS OF VIDEO)
- 6 PARTICIPATING INSTITUTIONS, 3 COUNTRIES

between all involved and a better understanding of microbialite communities and their presence and distribution in cenotes and caves in Quintana Roo.

Over three days of diving, CINDAQ provided diving support and expertise to collect microbialite samples, water samples and YSI water chemistry profiles at depths of 20m, 30m, 40m, 50m, 60m, and 71m.

Additionally, CINDAQ team members were able to document underwater collection sites with video, photos and photogrammetric models, as well as the surface with drone maps and imagery.

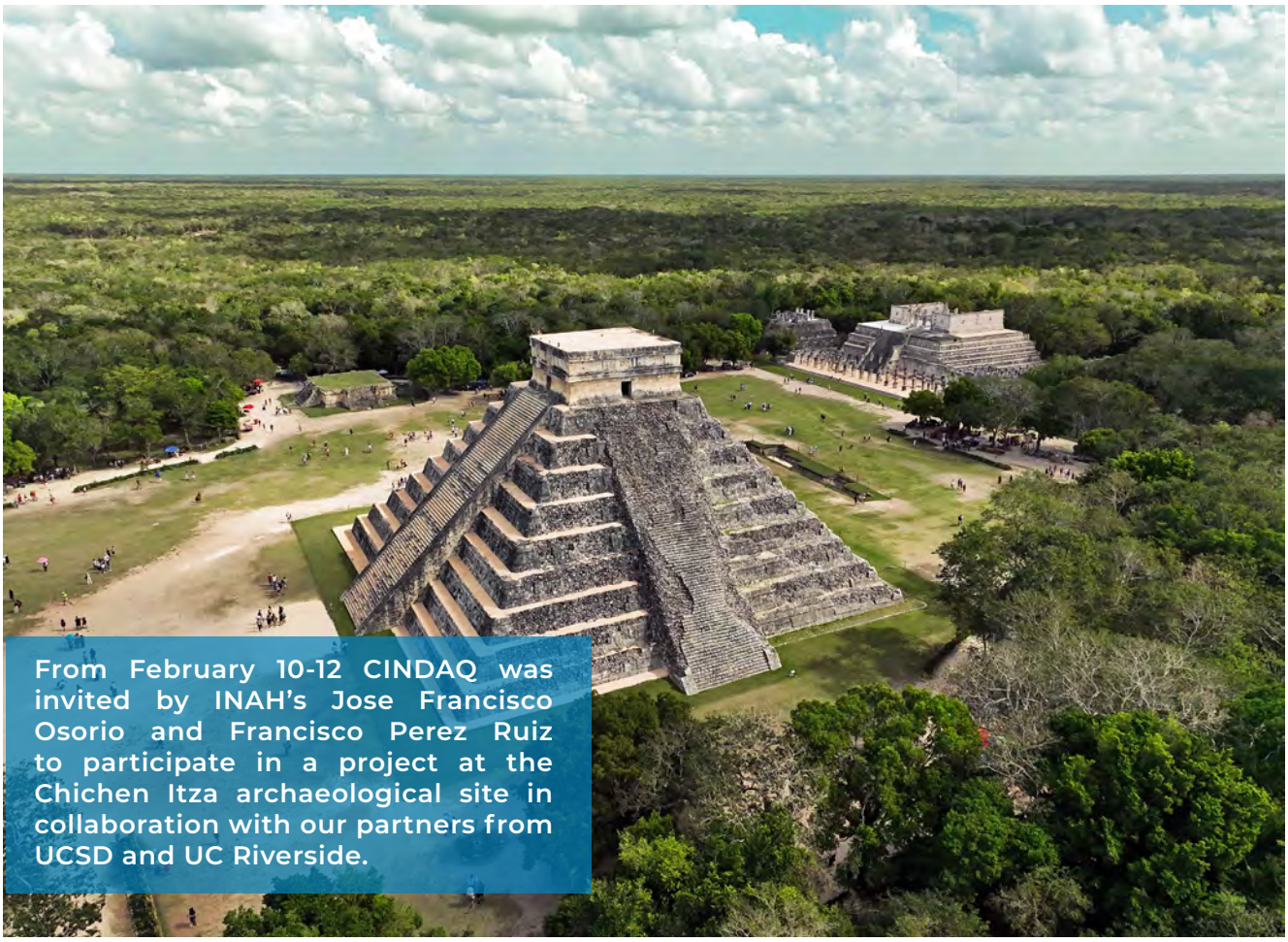




An afternoon of community outreach coordinated by Dra. Falcón and Prof. Martin Maas of el Colegio de Bachilleres Bacalar allowed the researchers and the CINDAQ team to interact with 50 local high school students.


> An opportunity to bring together local students, divers as well as researchers from Mexico, Canada and the United States

INAH CHICHEN ITZA PROJECT



From February 10-12 CINDAQ was invited by INAH's Jose Francisco Osorio and Francisco Perez Ruiz to participate in a project at the Chichen Itza archaeological site in collaboration with our partners from UCSD and UC Riverside.

Over two days we used our drones to not only **map the entire site from above** but also to create **digital twins** of El Castillo, the facade of the Casa de las Monjas complex, and the entire Akab Dzip structure.

> "Allow anyone to virtually access any corner of Chichen Itza without impacting it"

Additionally, aerial 360 images were created above the major structures and features of the site using Drone Deploy.

While we mapped with drones, **teams from UCSD and INAH** collected **high resolution scans of the interior spaces and exterior features of structures** from across the site. It was an incredible experience to be able to work in such an important and world renowned site and to collect this valuable data that provides a baseline on the site's condition. What is most exciting is the idea that this data will allow anyone in the world to be able to virtually access any corner of Chichen Itza without having an impact.

We appreciate the trust that INAH bestowed upon us to work on this project and want to thank Jose Francisco Osorio, Francisco Perez Ruiz, Travis Stanton, Dominique Rissolo, Scott McAvoy and everyone from INAH & INAH-SAS that participated. Our time there coincided with the filming of National Geographic Society documentary 'The and Fall of the Maya'. Sam and Dominique were interviewed and appeared in one of the episodes.

The results of this collaborative effort can be seen on *cindaq.org/chichen_itza* and *cindaq.org/rise_and_fall*

INAH EK BALAM PROJECT

Based on the positive experience of using our drones for surface mapping at Chichen Itza, we were invited to **produce a site map and photogrammetric models** of the main structures at the archaeological site of Ek' Balam.

Over two days from July 18-19 and under the supervision of the site director Archaeologist **Leticia Vargas de la Pena** and Archaeologist **Alejandra Alonso Olvera** who directs the Ek' Balam Archaeological Conservation Project, point cloud data sets were created of the entire site, the main acropolis, the ball court and a number of panels and sculptures from around the site.

> "An incredible resource for present and future researchers"

Furthermore, aerial and terrestrial 360 photos were obtained using Drone Deploy. Dr. Travis Stanton of UC Riverside was also on site to conduct laser scans of interiors as well as the famous stucco statues at the top of the main acropolis.

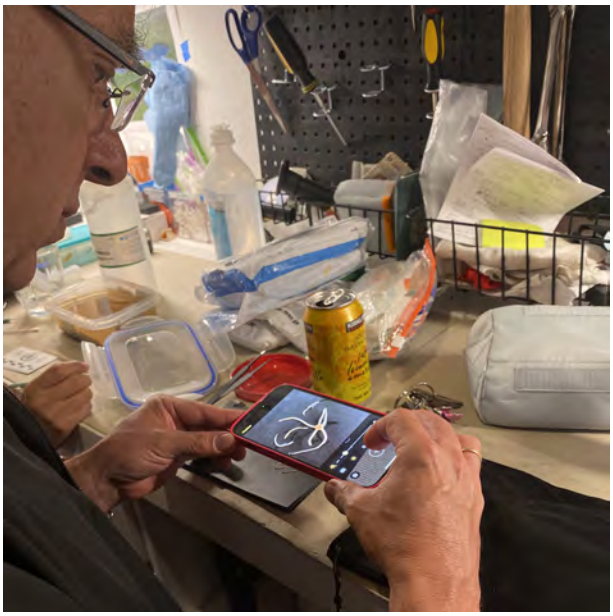
The data collected, as in the case of Chichen Itza, helps to create not only a baseline of the site but also an incredible resource for present and future researchers and students from Mexico and around the world. It was amazing to be able to spend time with both Leticia and Alejandra and their teams and witness the important work they are conducting in order to better understand and conserve Ek' Balam.

Once again we are **extremely grateful for the amount of trust placed in us by Leticia and Alejandra**, and we look forward to more collaboration in the future.

NEW SPECIES OF BRITTLE STAR

Brittle stars are echinoderms that belong to the class Ophiuroidea, which is a highly diversified group with approximately 2,064 known species, almost all occurring in marine waters. The rate of description of new species within this group began to level-off over the last couple of decades. The more diverse regions are the Indo-Pacific, then the North-Pacific, South-Pacific and West-Atlantic. About one third of the West-Atlantic species (98 out of 335 species) occur in the Mexican portions of the Gulf of Mexico and Caribbean Sea (Laguarda-Figueras et al., 2009; Stöhr et al., 2012).

Exploration and observation by CINDAQ have detected what, most probably, represents **a new species of brittle star** from an anchialine environment.



This **discovery**, made in the middle section (approximately 4 km from the coastline) of the **southern branch of the Ox Bel Ha system**, has prompted an investigation by **Dr. Fernando Alvarez of UNAM** that is currently in progress. This is truly a very rare occurrence, currently only two species of anchialine brittle stars have been described, one from the Bahamas and one from the Ryukyu Islands, Japan (Okanishi & Fujita, 2018). Systematic surveys conducted in this area of Ox Bel Ha show that there is an established population of these brittle stars.

Dr. FERNANDO ALVAREZ

Dr. Fernando Alvarez is an aquatic invertebrate biologist with a **special interest in crustaceans**.

He obtained a B.Sc. degree from Facultad de Ciencias, UNAM; a Master's from Tulane University, New Orleans, Louisiana; and a PhD from the University of Maryland, College Park, Maryland in the USA. He is a **full Professor and Curator of the National Crustacean Collection at Instituto de Biología, UNAM**.

He has been Editor in Chief of Revista Mexicana de Biodiversidad since 2011 and has been recognized with the level 3 at the National Researchers System of CONACYT, Mexico.

He has authored **186 scientific publications**, including 133 journal articles, 35 book chapters, 10 books and 8 contributions for the general public.

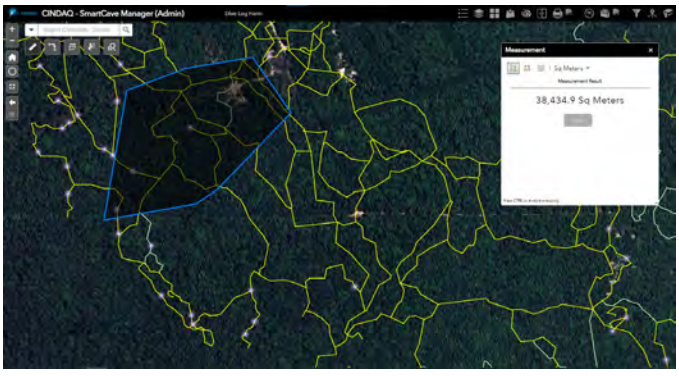
VIROLOGY STUDY - UPDATE

In 2022 CINDAQ assisted **Dr. Chris Beierschmitt, Dr. Andres Sanchez Quinto, and Jenna Acquino MSc.**, by collecting water samples from sites throughout the Ox Bel Ha system to **better understand microbial populations** and how they are distributed throughout the diverse microenvironments within this system.

This work was accomplished in part by the generous donation of metagenomic sequencing and analysis services by Illumina, in addition to multiple water analysis techniques to investigate the relationship between salinity, temperature, micronutrient composition, pH, and other metrics in relation to the bacterial, viral, and archaeal populations.

Preliminary analysis of the **data suggest that there are over 17,000 species represented from over 1,000 families**. To our knowledge, this appears to be the largest metagenomic analysis of an underwater cave system to date. A draft manuscript for this study is currently in progress.

GEOGRAPHIC INFORMATION SYSTEM (GIS)



While our team keeps getting more proficient in the **daily use of our Geographic Information System (GIS)**, updating the cave information available online after each dive, we also come up with new ideas on how this powerful tool can help us study the aquifer more efficiently.

2023 has seen us using GIS to model the **halocline depth** over the entire Ox Bel Ha system by calculating coastal distances of various points of the cave and matching them with divers' comments.

We used it to **create buffer zones** around our survey data to highlight land areas that could impact underground waters. From a diving perspective, we have harnessed its capabilities to highlight areas of missing survey data and **potential exploration** for our core teams and our helpful volunteers.

We also revamped the digital forms we use to document a variety of features, as well as the process of data importation from Ariane. This will allow us to perform more big data analysis on points of scientific interest in the cave, as well as to potentially **improve our dive planning** by transforming our survey data into a network data set that can be solved and studied more efficiently, in a similar way to how Google Maps functions.

Thanks as always to the expert support of Dr. Wetherbee Dorshow, of Earth Analytic Inc.

WIKINDAQ

In 2022, the CINDAQ team faced the need for a system to store our numerous SOPs, documents, memos, cheat sheets and instructions regarding all tools and aspects of our work. This included, but was not limited to, methods for data collection, processing and storage, office procedures, GIS workflows, maintenance tips for dive gear, troubleshooting steps for survey devices, recommended photogrammetry parameters, and much more. In order for this to work everything needed to be organized and stored in an easily accessible, searchable manner.Thus WIKINDAQ, our internal Wiki, was born, and by the end of 2022 we had reached 100 articles.

WIKINDAQ : KEY FIGURES

- **200+ ARTICLES**
- **12 CATEGORIES**

2023 saw a further increase of the WIKINDAQ content, with another 100 articles created this year. Furthermore, we focused on 3 main development axes for the system:
1. The creation of **complete workflows** to link relevant articles into complete sets
2. The implementation of a proper **user management system**
3. The configuration of a **backup system** for WIKINDAQ

While the first articles tended to be rather short tips and tricks or troubleshooting instructions for a specific issue, we quickly ended up seeing the potential for creating complete workflows linking these shorter articles into comprehensive sets of instructions. The different articles on photogrammetry, for instance, are now interconnected into a bigger, organized article chronologically listing all the steps required from preparation to publication for a 3D model. This not only serves as a cheat sheet for our team, but also **ensures standardization and consistency for the data produced by us and our partners**, and thus the quality of the scientific work based on them.

Thanks to the user management system, we are now able to create accounts for the different team members, as well as volunteers and partners on CINDAQ projects. This not only allows us to **share relevant information with our extended team**, but also to manage reading, editing and deletion rights.

And the new backup system has our backs in the unlikely event that a user should make a mistake.

NEW CINDAQ WEBSITE

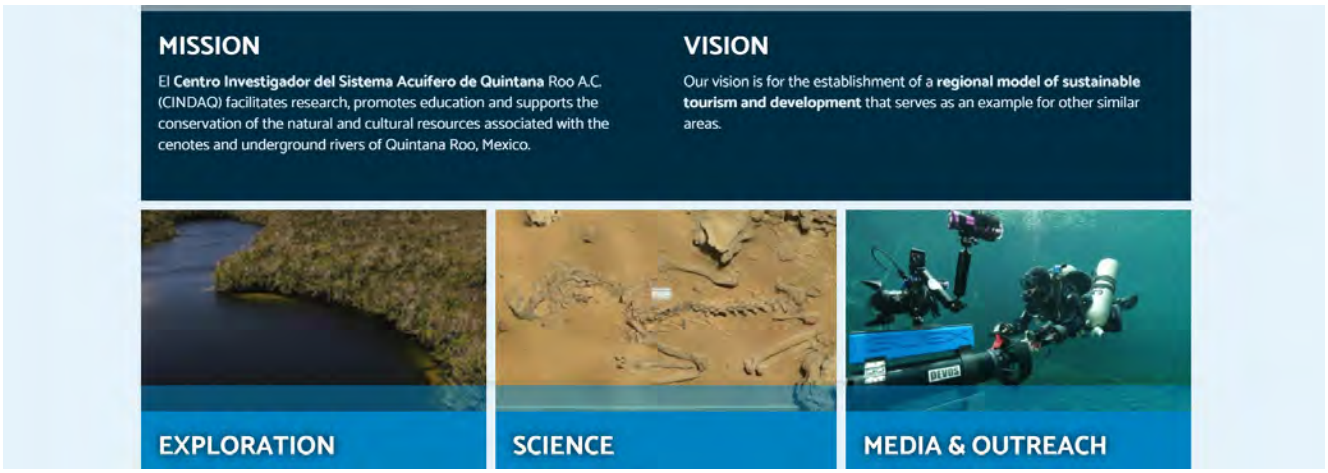
Over the past couple of years, and after each phase of every project, we created **web-based reports for our institutional partners** to share our results. This not only allowed us to have a relatively quick turn-over, with reports usually being available within two weeks or less, but also to provide our partners with links to downloadable material (documents, maps, media, etc.) representing the latest version of all data.

While this method has proven very useful, we wanted to **bring it to the next level with a more modular approach by creating a brand-new website** with a complete user and group management system. Each web-based report would thus not only be linked to one unique link, but to personal accounts or groups, thus offering more flexibility not only to the CINDAQ team, but also to our partner NGOs, universities and government institutions .

Furthermore, we have worked on several different solutions in order to **embed access to point cloud models of our photogrammetry projects**, both for underwater and at the surface, making them easily available to our partners on the new website. We have also experimented with various methods to share large amounts of downloadable data with our partners, without compromising security to our centralized repository.

In 2023, **we partnered with the Indian company GoPadma**, whose Director Nicolas Deboissy and his team are working with us to create an integrated solution including the current content and spirit of the CINDAQ website with the challenges of complex user management, point cloud streaming and large data sharing.

We are happy to launch the new website with this new year 2024, and are looking forward to a continued collaboration with GoPadma in the future.



GEMINI CCR COURSE

In July, we hosted **Jon Bernot** for rebreather sidemount training on the **Fathom Gemini sidemount CCR**. Jon is an experienced cave instructor and explorer based in Florida with whom we have trained in the past.

Our interest in CCRs lies in **deep cave exploration** where gas efficiency adds significant advantage. A sidemount rebreather offers a large degree of flexibility with cave logistics especially when project diving takes us to **more remote areas** like Sian Ka'an. Additionally with a constant partial pressure of oxygen, we are able to optimize decompression and team safety.

In the last few years, we have evaluated a number of different sidemount CCR units. The split canister scrubber design has grown in popularity, as it offers a streamlined, well balanced, and clean configuration necessary in low cave areas.

The Gemini mCCR is a split scrubber design with axial scrubber baskets. The oxygen addition is controlled with a needle valve, and allows the divers to adjust oxygen flow to meet their metabolic rates. A dual MAV (Manual Addition Valve) is used for all gas addition to the unit. The Gemini has two distinctive ways to monitor the partial pressure of oxygen (PO2). One way is with a Heads Up Display (HUD), and the other with the Shearwater Petrel 3 handset.

The Gemini is the **most sturdy, well engineered unit we have tried to date**. We are thankful to Jon for sharing his experience, and excellent training with us here. We have one more unit left to evaluate before we decide on which one to invest in.

RBK: KEY FACTS & LEARNINGS

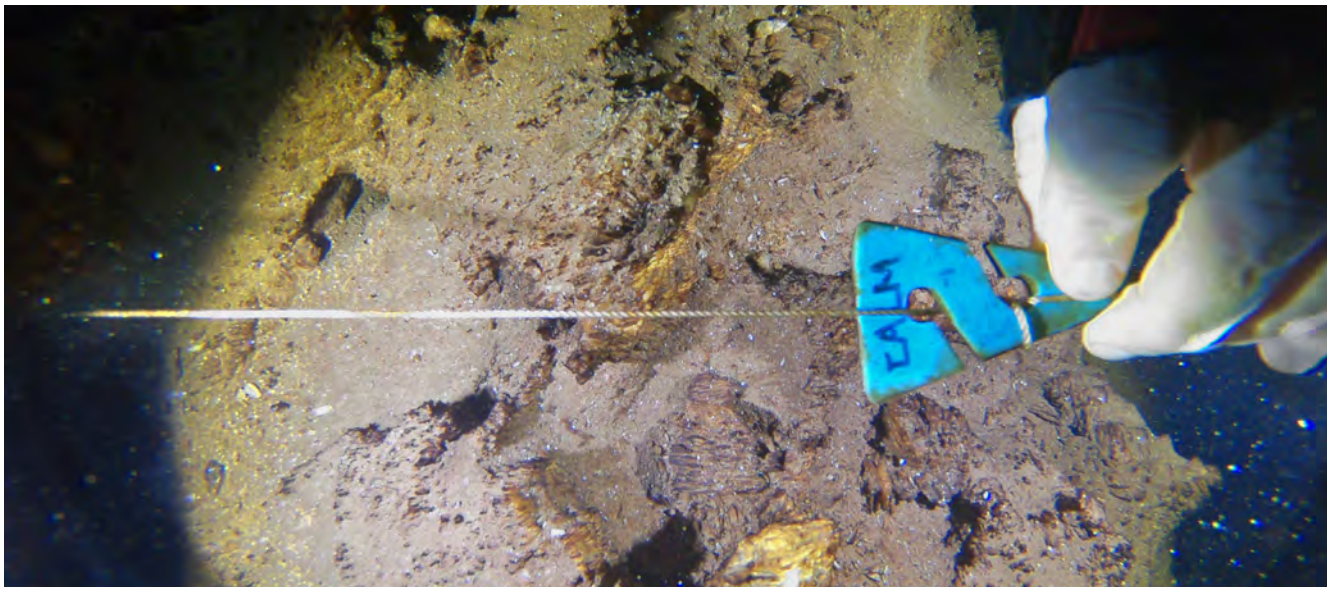
The Halcyon RBK side-mounted, passive-addition, semi-closed rebreather is an adaptation of the well-proven concept of the Halcyon RB80, originally developed by Reinhard Buchaly (RB) in 1996 for the cave exploration dives conducted by the European Karst Plain Project (EKPP), and later extensively used by the Woodville Karst Plain Project (WKPP) in Florida. A purely mechanical unit keyed into the diver's breathing, the RB80 does not depend on fragile electronics, and has a robust flood-tolerant design.

While the RB80 has shown, over decades of heavy usage, to be a sturdy and reliable machine allowing impressive cave penetrations, the new, side-mounted version RBK has been designed to access underwater caves where a more streamlined profile is preferable. The RBK allows cave divers to access more restricted areas of the caves located beyond restrictions not passable using a back-mounted version. It **can also be used as an additional, or removeable, independent rebreather** in conjunction with traditional backmount open circuit and CCR systems. Furthermore, remote cave entrances requiring either long walks or single rope techniques (SRT) are more easily accessible when the rebreather setup is both more compact and more modular, making the RBK a useful exploration tool for a broad array of caves, and potentially limiting the impact on a diver's back.

The new RBK design is based on smaller, different dimensions, which affect the gas ratio achievable, and thus the oxygen drop in the breathing loop, as well as the decompression obligations. Though the real-life values can vary depending on the dive parameters and the diver, a ratio of 1:6 seems to have been quite consistently achieved, which roughly translates into 31% oxygen in the loop when injecting 36% at 18m, or 32% when injecting 40% at 9m.

With well over 5,000 hours of diving collectively within the CINDAQ team, the RBK has shown to be a very valuable tool for cave diving exploration from the surface to 30 m, benefitting from the simplicity & sturdiness of the RB80 while allowing access to more restricted parts of the caves. While the machine can penalize divers with longer decompression obligations compared to CCR on deeper dives, and has a tendency to overpressure the loop when in positive trim, in over three years, **not a single dive has been canceled pre-immersion** because of an RBK failure, and only two dives have resulted in a unit flooding. While we can use CCRs on deeper dives or specific projects, **the RBK will remain our daily tool for long dives in relatively shallow caves** with high workload on the divers, where the main focus needs to be kept on the task and not on the machine being used.

DIRECTIONAL MARKERS - USE & CREATION



When exploring caves there are many decisions to be made, such as what gear configuration to use and dive team selection. But, the most critical decisions that are made on every dive have to do with navigation within the cave. Our very lives depend on making the right decision every time to ensure that we safely exit. One question that is often overlooked is what we write on our plastic directional markers (DM's) and how that can enhance safety.

DM's serve a very important function to indicate the direction out of the cave while also marking intersections (T's and jumps) and possible leads where the cave may continue.

While the markings written on a DM may not necessarily be important for the execution of a 'normal' cave dive, they are **important for extremely complex navigation** (enhancing safety by providing a clear frame of reference), and increased detail and accuracy in large scale survey and resurvey, such as that of Ox Bel Ha. What is written on a DM can also aid us in our exploration efforts particularly when connecting one line into another.

There are a number of strategies that have been employed by divers to mark their DMs over the years. While some just leave them blank, others may opt to put their name and sometimes the year of exploration. Oftentimes, divers will write unique and often funny names on the DMs or use an alphanumeric system. **Unmarked DM's make it very difficult to navigate the cave** by directions. They also make it impossible to attribute the exploration to any team or diver during later resurvey. Alphanumeric sequences are hard to remember, while unique names are not.

As an organization, and through almost 30 years of experience, CINDAQ believes that having a clear system for marking our DM's is critical to our team's safety and survey efforts.

```
andreas@hypoxic ~/repos/cindaq-github/cindaq_dm_generator  master  cat new_list.csv
TCS,TODA,SORES,MEATH,VIBE,WOKEN,DAYS,HEAPS,IPSUM,DAR,TUNED,MESON,METH,CHARD,LIAO,KBD,WASPS,UBID,U
AW,PICT,ISIS,TERA,MARIE,VETO,WYATT,TGP,PAULS,UNCLE,GNATS,IHR,KINJA,DUB,WORE,TULIP,LISLE,OMIM,SCAR
S,ALLIS,CAPRI,DWF,EXAM,MEWN,DWR,COMPO,NEM,ADEN,BJORK,NHHS,SANS,CORFU,LANTA,BOWEN,VISAS,JPG,JDJ,PA
V,PIMP,MIST,ADC,NAMES,VOWED,NSF,HAR,THC,COLM,QUIRK,TONK,AWW,SUING,RTM,BOI,VERDE,TER,OULU,PMP,ICR,
DLP,COH,BULK,SUES,ATARI,HOTEL,FODOR,DSP,USM,DARIO,ESRB,LOFT,LIND,INCH,PAIGE,FURRY,RONIN,EFS,TOBEY
,MAMMA,AFR,MATA,PDE,ANA
```

When one considers that there are now over 7,683 directional markers, over 2,500 jumps and over 1,500 T's in the Ox Bel Ha cave system and that on a 'typical ' dive we may have 15 to 20 navigational decisions to make, the importance of what is written

on a DM becomes clear.
As a result, **a python-based script** was created this year in an effort to clarify and streamline the process of what actually is written on them and to avoid the use of the same word twice.

The basic strategy we employ is to mark all of our DM's with unique words in addition to the name 'CINDAQ' and the year in which the marker was placed. For many years we would use random words; the names of famous people, words from songs, or movies that we were familiar with. We would also sometimes use a running alphanumeric number scheme, but eventually found it was easier to remember and distinguish between unique words like "Bühlmann" or "Haldane" than "E4C8" and "E4C9".

After using this random method for years we noticed that, by accident, we had quite a few duplicate names within Ox Bel Ha, which could create confusion. It was because of this that we decided we could overcome this problem using software to search through the existing line marker names in our survey data and create unique names to prevent repetition.

Due to the small size of DM's, we opted to use short words of maximum 5 letters. We also chose to limit words to Spanish and English as most people here are familiar with either or both. To do this we wrote a python script parsing the cave survey (XML) file created by our main survey tool Ariane containing all of our comments. In our survey comments the letters "DM" signifies that there is a directional marker at that particular station.

To **ensure unique names** while keeping them short and sweet we first need to ensure they do not exist anywhere else in our survey. The script selects all the words in the CM XML element that started with the letters "DM" and makes a unique list of already used words. Then, it is just a matter of randomly selecting short words from a randomly generated wordlist and cross referencing it with the words that have already been used. As a failsafe, we then save the generated words in a reference list so we can not create a duplicate of that word when the DM has not yet been added to the system.

As we have resurveyed Ox Bel Ha, we have encountered DM's from past explorers, in some cases the original writing has become illegible making us realize that we also needed a new method for ensuring that what is written on a DM will last well into the future.

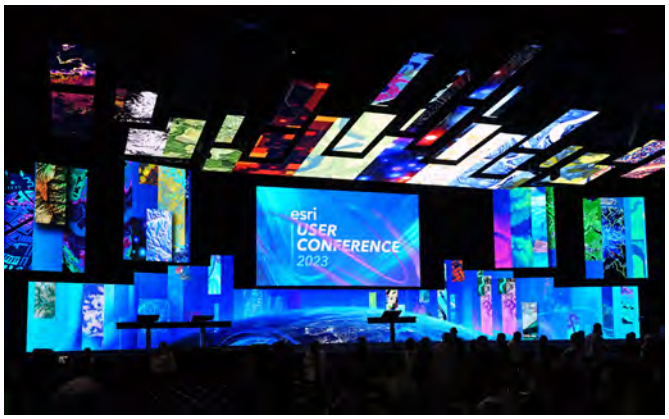
Teammate Jose Luis Hernandez has been hard at work using punch sets to punch stamp our DMs in addition to marking them with a permanent marker. This ensures that the DM names are **possible to read much longer** than when only using a permanent marker.

OX BEL HA & DIRECTIONAL MARKERS

- 7,683 DIRECTIONAL MARKERS
- 2,500+ JUMPS
- 1,500+ T INTERSECTIONS

Many thanks to Halcyon for their ongoing support with directional markers!

ESRI USER CONFERENCE - JULY 2023, SAN DIEGO

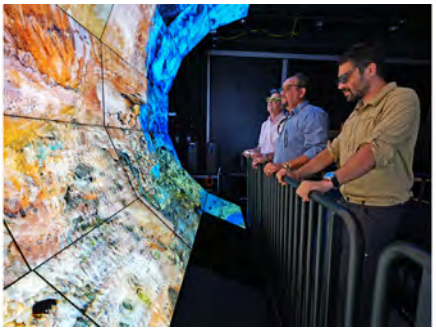


From July 10-14, Sam and Julien attended the **2023 ESRI Users Conference in San Diego, California**. Our attendance allowed us to spend time with our partners from Earth Analytics Inc, and The Puente Institute as well as to attend sessions and interact with the people and companies that dedicate their time and efforts to the GIS industry. **Wetherbee Dorshow of Earth Analytics Inc.** was able to introduce us to key people at ESRI who took a great deal of interest in how CINDAQ is using GIS. This led to a number of discussions on new development ideas related to using GIS to help us better understand the hydrology of our areas caves, network solving and offline solutions.

We were also able to connect with vendors, including the Dell ruggedized computer division who, as a result, have donated three ruggedized computers to CINDAQ for field work. We are **especially grateful to David Plourde of Dell Technologies** for making this happen. Sam was also able to reconnect with longtime friend of CINDAQ, **Dr. Sylvia Earle and her team from Mission Blue**. We hope that Dr. Earle will someday be able to come for a visit to Quintana Roo.

We are also grateful to long-time supporter of CINDAQ **Brian Strauss** for kindly letting us stay at his lovely home.

UCSD/SCRIPPS VISIT - JULY 2023, SAN DIEGO



While in San Diego, Sam, Julien and Wetherbee Dorshow took advantage of their time there to visit our partners at UCSD as well as the Scripps Oceanographic Institute.

As always it was a pleasure to visit the **Cultural Heritage Engineering Initiative (CHEI)** lab and see the amazing projects they are involved in. We were able to sit down with **Dominique Rissolo** and **Scott McAvoy** to get insight as to how we can more efficiently share our photogrammetric point cloud models using Potree, as well as discuss the solutions that will help us to share large amounts of data easily. Our relationship with CHEI continues to grow and prosper, we are grateful for their continued support.

At **Scripps** we were given a tour of the dive locker by diving safety officer **Christian McDonald** and learned more about one of the oldest scientific diving programs in the world.

MCEP / CINDAQ SCIENCE PROJECT- DECEMBER 2023

32 participants from 9 countries participated in the 6 day project co-hosted by the Centro Investigador del Sistema Acuífero de Quintana Roo (CINDAQ) and the Mexico Cave Exploration Project (MCEP).

The goals of this volunteer based project were to **contribute to a better understanding and appreciation of the caves** and related features of this region and meet, mingle and enjoy cave dives with fellow GUE trained divers.

Hydrolab profiles add valuable information to our database of spatial and temporal changes to the aquifer including seasonal changes, freshwater thickness and halocline position.

Sediment traps contribute to a **better understanding of relationship between the rate of sediment deposition and weather patterns** in order to use sediment core records to recreate the past 5,000 years of climate change in the region.

Additional HOBO sensors further help to refine our understanding of the temporal changes in temperature and conductivity of the freshwater lens and how this relates to meteorological fluctuations and events. Observations at calcite locations contribute to the understanding of where and when calcite forms by examining their deposition and water chemistry.

Special thanks to all involved in the December 2023 Science project!

SCIENCE WEEK 2023 : KEY FIGURES

- 32 VOLUNTEER GUE DIVERS
- 9 DIFFERENT NATIONALITIES
- 6 DAYS OF SCIENCE WORK
- 4 WATER CHEMISTRY PROFILES
- 14 SEDIMENT TRAPS REPLACED
- 4 HOBO SENSORS DOWNLOADED
- 20 CALCITE LOCATIONS VISITED

VIDEO DOCUMENTATION CAPABILITIES

In 2023 we shot footage underwater, at the surface, and did sit-down interviews in order to highlight the importance of our many scientific and institutional collaborations. This included capturing **the beauty of cenotes and caves**, and the amazing wildlife that inhabits them.

The addition of a 90 mm macro lens and a 400-600 mm lens now gives us the full range to get **incredibly detailed imagery**. With over 400,000 lumens of battery powered underwater lighting, we can now illuminate the caves wherever we choose, taking the audience with us to experience the incredible environment of the cenotes and caves.

In addition, we provided sponsors with testimonial videos and had one of the major landmark BBC series we worked on in 2022 go to air.

We now have **a substantial library of high quality video imagery** that we can begin to make use of. We have begun to receive outside help from media expert Tona Rangel Silvas in both editing and filming.

In 2024, we plan to begin to produce short informative videos about the aquifer and our work to better understand it.

BBC - PLANET EARTH

We are very pleased that **BBC Planet Earth III was released on October 22 in the United Kingdom**, and shortly after to the rest of the world. The series aired in the United States on BBC Americas, AMC+ and Apple TV starting in November.

The sequence we filmed last year was featured as the opener for **Episode 4: Freshwater**. The Planet Earth series is highly regarded as one of the most significant natural history series ever to be produced.

With **a projected audience reach of over 1 billion viewers**, we are excited to see the impact that it will have. Many thanks to BBC producer Estelle Cheuk for her time and dedication while here in the field with us, and our gratitude to **our good friend Mike Madden** whose expertise and guidance made it all possible.

Both Fred and Mike received credit for the filming of the sequence which will go a long way to garner interest in more high caliber filming projects.

cindaq.org/pe3

BBC/NBC THE AMERICAS

In addition to the original footage filmed in 2022 for **the BBC/NBC 'The Americas' series**, CINDAQ also submitted a large amount of footage of cave biology obtained over numerous dives in 2023. This included exclusive macro footage of a new troglobitic species the CINDAQ team discovered which will be seen for the first time in this landmark series.

The 10 part series "explores the wonders, mysteries, and fragilities of the Americas, as well as telling extraordinary, untold wildlife tales". It is set to be released mid 2024 **with the actor Tom Hanks as the narrator**. It will also feature original music by two-time Oscar winner Hans Zimmer. It is expected to reach a projected audience of 350 million viewers around the world and can only help to get more people interested in the caves and cenotes of the peninsula.

Due to the positive feedback we received for the imagery we captured for 'The Americas', we were commissioned to film a behind the scene sequence highlighting the challenges that were involved filming the tiny biology found in the huge caves of our area. With the help of local cameraman Tona Rangel Silvas were able to complete the shot list requested by the BBC including drone footage, interviews and surface action. The sequence is scheduled as an add on to the episode on Mexico.

SUEX TESTIMONIAL VIDEO

In March, SUEX Stories Episode 14 'Sharing Knowledge: CINDAQ' was released.

This short video used footage captured in 2022 by CINDAQ. This testimonial video provided the opportunity to speak about CINDAQ's efforts and goals and reached more than **100,000 viewers** through the SUEX website and social media platforms.

While their diver propulsion vehicles (DPVs) are **the "driving force" that get us to and from our underwater work areas**, SUEX has also provided us with their innovative 'Zero Frame' camera mount which allows us to capture smooth imagery underwater.

We are grateful for the support we receive from SUEX and their North American and Mexican distributors: **D3 Diving and Zero Gravity Dive Center**.

cindaq.org/suex

ADDITIONAL VIDEO PROJECTS

Bacalar Microbiology Project

As part of our May project in support of Dra. Luisa Falcon, we created a short film on her work in the Bacalar area. This short film was shown during the official Bacalar Municipal Day of the Stromatolite in July where it was well received. We look forward to creating other similar films to focus on our collaboration with the scientific community and our collaborations with them. We are grateful for the work of Tona Rangel Silvas did to edit the film.

cindaq.org/bacalar

Nauticam Show Reel

Our supplier of underwater filming equipment, Reef Photo & Video, requested a show reel of footage captured using Nauticam products for use by them and Nauticam at dive expos around the world. We were vey happy to oblige, as most of our underwater filming is done with Nauticam camera housings, monitor housings, and lens ports including the WACPII wet lens. The footage was very well received at both the ADEX show in Singapore and the DEMA show in New Orleans. We are grateful to Reef Photo & Video and Nauticam for their continued support.

cindaq.org/nauticam

Sian Ka'an Biosphere Reserve

Our May visit to Cenote Tuun Ja and the Xamach-Muyil forest fire site provided the opportunity to document CONANP's efforts to study the regeneration forest fire sites as well as on-site interviews with both the director and sub-director of the Sian Ka'an Biosphere Reserve.

Interviews

Seven formal interviews were conducted in order to provide a more direct connection to the subject matter while maximizing the use of our growing inventory of film equipment.

- Dr. Fernando Alvarez
  Biologist UNAM
- Biólogo Felipe Ángel Omar Ortiz
  Director, Sian Ka'an Biosphere Reserve
- Biólogo Oscar Guzmán Escalante
  Subdirector, Sian Ka'an Biosphere Reserve
- Dr. Luisa Falcón
  Microbiologist UNAM Merida
- Sam Meacham
- Fred Devos

PARTNERSHIPS & COMMUNITY ENGAGEMENT

Throughout 2023 we have maintained **our presence in the local watershed management committees**. We believe in the strength and importance of these committees and collaborative platforms, and we participate in order to provide our knowledge and experience, as well as scientific and technical advice to municipal and state representatives, always with the objective of contributing to a better and more sustainable management of the region's water resources.

We continue to work side by side with our federal partners from **La Comisión Nacional de Áreas Naturales Protegidas (CONANP)**, in particular with the management of the Sian Ka'an Biosphere Reserve. Our project reports within the reserve are now being passed up to the highest levels of CONANP.

We also have continued to develop our relationship with **INAH-SAS, INAH-Yucatan Peninsula and INAH-Mexico City**.

As a medium-term objective, we would like to establish a more fluid relationship with organizations that work on common objectives, such as **Centinelas del Agua, Cenotes Urbanos, Cenoteando/UNAM Sisal**, and the **Healthy Reef Initiative for the Mesoamerican Reef System**.

COMMUNITY SUPPORT

As part of our ongoing efforts to aid local Quintana Roo communities, we continue to seek out meaningful opportunities to provide support.

During 2023, **Roman Caamal, President for the Regional Mayan Community Tourism Network**, approached CINDAQ in order to seek support towards the expenses so that local community members could attend two large tourism fairs in Europe (France and Estonia). Their objective was to promote the Maya Ka'an area as a sustainable and culturally distinct destination, thus bringing tourist dollars to marginalized communities further south in the state. CINDAQ agreed to support this trip and made a donation towards the expenses of those who participated in the trip. We are excited to be able to support the advancement of sustainable tourism initiatives within the communities that guard the cultural and environmental richness associated with the cenotes.

Additionally, CINDAQ supported the Cenotes Urbanos project with a gift in kind of much needed equipment (an inflatable kayak, lights etc.) that they can provide to their volunteers for cenote research and rehabilitation. We continue to be impressed with **the incredible work of Cenotes Urbanos and the leadership of Biologo Roberto Rojo**.

UNESCO CONFERENCE - APRIL 2023, COZUMEL

CINDAQ was invited to attend the First Intersectoral and Technical Meeting on Best Practices and Underwater Cultural Heritage, which took place in **Cozumel** from April 12 to 14.

The meeting was co-organized with the Municipal Government of Cozumel and the National Institute of Anthropology and History (INAH), Mexico. The meeting sought to generate a **dialogue on the initiatives of best practices of responsible access to underwater cultural heritage (UCH)**, and on the new means to facilitate this access and modern technical advances. It also drew attention to the impact of industrial and tourism activities, mitigation methods, responsible management and possible impacts. The meeting focused, at the same time, on issues such as groundwater management and biodiversity in the Maya region and the Gulf of Mexico.

Representatives from ten countries (Belize, Colombia, Cuba, Costa Rica, Dominican Republic, Guatemala, Honduras, Panama, Mexico, Nicaragua) participated in the event, as well as representatives from UNESCO, UNESCO Mexico, INAH and INAH-SAS. Sam gave a 15 minute presentation on the first day about the work of CINDAQ and the biocultural importance of the cenotes and underground rivers. The presentation was very well received and opened up the doors for a number of opportunities.

The takeaway from the conference is that CINDAQ is now a well-respected organization that is being sought out as **experts on data management, GIS (in conjunction with Puente Institute and Earth Analytic), diving skills, and scientific diving methodology** both nationally and internationally.

UNESCO CONFERENCE - JUNE 2023, PARIS

From June 14-16 Sam and Julien attended the statutory meetings of the **2001 Convention on the Protection of the Underwater Cultural Heritage in Paris**, France.

Over 3 days, they were able to observe the Ninth session of the Meeting of States Parties to the 2001 Convention on the Protection of the Underwater Cultural Heritage, the Fourteenth Meeting of the Scientific and Technical Advisory Body (STAB), and attend a meeting of the **UNITWIN Network for Underwater Archaeology** and a **meeting of the accredited NGOs to which CINDAQ belongs**. It was a wonderful opportunity to finally meet face to face with the other NGOs after years of video conference calls, share experiences and continue to help advance the NGO database. While the inner workings of UNESCO are fairly bureaucratic, it was nevertheless fascinating to see how things get done at this level of governance.

We are grateful for the time we were also able to spend with Mexico's representative for the 2001 Convention **Helena Barba Meincke** which allowed time to discuss future projects in the Yucatan Peninsula where CINDAQ can potentially lend its support.

We are also **grateful to Ulrike Guerin of UNESCO** who orchestrated not only the meeting in April in Cozumel but also the meeting in Paris. We look forward to years of continued collaboration.

PUBLICATIONS & CONFERENCES

PUBLICATIONS

The following are publications directly or indirectly associated with CINDAQ in 2023:

Álvarez, Fernando, Brenda Durán, Samuel Meacham (2023). *Mexican Fauna in the Anthropocene: Anchialine Fauna of the Yucatan Peninsula: Diversity and Conservation Challenges*, edited by Robert W. Jones, C. Patricia Ornelas-García, Rubén Pineda-López, Fernando Álvarez, pp. 287-301, Springer Cham.
cindaq.org/anchialine_fauna

Chatters, James C., H. Gregory MacDonald, Blaine W. Schubert, and Joaquin Arroyo Cabrales (2023). *Cenotes, Caves, and Sloths: Pleistocene Sloth Diversity on the Yucatan Peninsula, Mexico and Belize*, Journal of Cave and Karst Studies (in press).

Choi, Charles Q., *La Mina: The Mysteries of Quintana Roo, Part 1*, The Mammoth Trumpet, Texas A&M University Press, Volume 38, Number 3, pp. 5-11 (2023)

Choi, Charles Q., *La Mina: The Mysteries of Quintana Roo, Part 2*, The Mammoth Trumpet. Texas A&M University Press, Volume 38, Number 4, pp. 1-3 (2023)

Rojas Sandoval, Carmen, Miguel Covarrubias Reyna, and Dominique Rissolo (2023). *Constructing a World Beneath Quintana Roo*. In Constructing Space: Causeways, Walls, and Open Areas in the Ancient and Historical Maya Landscapes, edited by Thomas Guderjan and Jennifer Mathews. Tucson, University of Arizona Press., pp. 337-371. University of Arizona Press.
cindaq.org/maya_space

Glover, Jeffrey B., and Dominique Rissolo (2023). *Coastal Settlements and Identities and the of the Itza*. In When East Meets West: Chichen Itza, Tula, and the Postclassic Mesoamerican World, edited by Travis W. Stanton, Karl A. Taube, Jeremy D. Coltman, and Nelda I. Marengo, pp. 409-426. BAR Publishing, Oxford, UK.

Moyes, Holley, Dominique Rissolo, Hilda Lozano Bravo, Eric Lo and Shane Montgomery, and Amy Newsam (2023). *Maps and Imagery: A Hybrid Model for Analyses and Interpretation of Archaeological Cave Sites.* Research Reports in Belizean Archaeology, Vol. 18, pp. 91-102. Institute of Archaeology, NICH, Belmopan, Belize.

McAvoy, Scott, John Ristevski, Dominique Rissolo, and Falko Kuester (2023). *OpenHeritage3D: Building an Open Visual Archive for Site Scale Giga-Resolution LiDAR and Photogrammetry Data*. ISPRS Annals of the Photogrammetry, Remote Sensing, and Spatial Information Sciences X-M-1-2023:215-222.
cindaq.org/visual_archive

Lozano Bravo, Hilda, Eric Lo, Holley Moyes, Dominique Rissolo, Shane Montgomery, and Falko Kuester (2023). *A Methodology for Cave Floor Basemap Synthesis from Point Cloud Data: A Case Study of SLAM-Based LiDAR at Las Cuevas, Belize*. ISPRS Annals of the Photogrammetry, Remote Sensing, and Spatial Information Sciences X-M-1-2023:179-186.
cindaq.org/cave_floor

Steele, Riley E., Eduard G. Reinhardt, Frederic Devos, Samuel Meacham, Chris LeMaillot, Jeremy J. Gabriel, Dominique Rissolo, Cesar Arturo Vera, Matthew C. Peros, Sang-Tae Kim Matthew Marshall, Juliet Zhu (2023). *Evidence of recent sea-level and the formation of a classic Maya canal system inferred from Boca Paila cave sediments, Sian Ka'an Biosphere, Mexico.* Quaternary Science Reviews, Volume 310.
cindaq.org/boca_paila

PUBLICATIONS & CONFERENCES (CONT.)

CONFERENCE PRESENTATIONS

Chatters, James C., Vid Petrovic, Joaquin Arroyo Cabrales, Dominique Rissolo, Blaine Schubert, Alberto Nava Blank, Diana Arano, and Helena Barba Meinecke (2023). *Virtual Taphonomy and the Fate of the Pleistocene Age Woman from Hoyo Negro, a Submerged Natural Trap in Mexico*. Paper presented at the International Council for Archaeozoology Conference, Cairns, Australia.

Hadden, Carla S., Edgar Alarcón, Jeffrey B. Glover, and Dominique Rissolo (2023). *Oxygen Isotope and Radiocarbon Evidence for Climate Variability at Vista Alegre, a Coastal Maya Settlement*. Paper presented at 2nd Latin American Radiocarbon Conference, Mexico City.

Lozano Bravo, Hilda, Eric Lo, Holley Moyes, Dominique Rissolo, Shane Montgomery, and Falko Kuester (2023). *A Methodology for Cave Floor Basemap Synthesis from Point Cloud Data: A Case Study of SLAM-Based LiDAR at Las Cuevas, Belize*. Paper presented at the 29th International CIPA Symposium, Florence, Italy.

McAvoy, Scott, John Ristevski, Dominique Rissolo, and Falko Kuester (2023). *OpenHeritage3D: Building an Open Visual Archive for Site Scale Giga-Resolution LiDAR and Photogrammetry Data*. Paper presented at the 29th International CIPA Symposium, Florence, Italy.

Moyes, Holley and Dominique Rissolo (2023). *SLAM Dunk: Imaging Belizean Cave Sites Using Hovermap System*. Paper presented at the 88th Annual Meeting of the Society for American Archaeology, Portland, OR.

Rissolo, Dominique, Holley Moyes, Eric Lo, Hilda Lozano Bravo, Scott McAvoy, Shane Montgomery, Samuel S. Meacham, Helena Barba Meinecke, Falko Kuester (2023). *Critical evaluation of SLAM-based mobile LiDAR mapping methods for documentation of archaeological cave sites and subsequent integration with multimodal and multi-scalar datasets*. Paper presented at the 50th Computer Applications in Archaeology Conference, Amsterdam.

Rissolo, Dominique, Vid Petrovic, James C. Chatters, Alberto Nava Blank, Scott McAvoy, Danylo Drohobytsky, Samuel Meacham, Julien Fortin, Helena Barba Meinecke, Roberto Junco, and Falko Kuester (2023). *Submerged Late Pleistocene and Early Holocene Cave Sites on the Yucatan Peninsula: Recent Advances in Virtual Access and Visual Analytics*. Paper presented at the 56th Annual Conference on Historical and Underwater Archaeology, Lisbon, Portugal.

PUBLIC PRESENTATIONS

Jan. Lewis University of Minnesota Field School

Jan. Ecosystem Field Studies Program, Xpu Ha Field School

Jan. Cave and Wreck Night Amsterdam, The Netherlands

Mar. Georgia State University Anthropology Department

Mar. Georgia State University Geoscience Department

Apr. First Intersectoral and Technical Meeting on Best Practices and Underwater Cultural Heritage UNESCO Meeting Cozumel

May. Community of Bacalar, Cenote Azul

Jun. Community of San Manuel, June, 2023

Jul. Cenote Urbanos Noches del Inframundo

Aug. Casa Blanca Fishing Lodge

Sept. Entrepreneurs' Organization - Cancun Riviera Maya Chapter

Nov. GUE Conference

Nov. Colegio Tomas Alva Edison

Dec. CINDAQ/MCEP Science Project

DEDICATION: ZERO GRAVITY & CAFE CARIBE STAFF

Teamwork begins at the surface: we dedicate our report this year to **the amazing staff of Zero Gravity Dive Center and Cafe Caribe**. Behind the scenes Maria, Yolanda, Lucia, Rosa, Jorge, Pancho and Mariano keep us ticking by filling our tanks, repairing our equipment, providing **surface support**, and tidying up after us, to the essential cups of **coffee** that we consume to enhance our productivity. Their good humor and friendship is the most valuable daily contribution and we are always happy to see them at the beginning and end of every day. It is with **sincere gratitude** that we dedicate this report to them.





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CINDAQ
Surfacing Vital Knowledge

If you have any questions, or would like to support us, please feel free to contact us at **outreach@cindaq.org**

CINDAQ 2023 Report

Fred Devos, Julien Fortin, Christophe Le Maillot
Sam Meacham, Daniel Ponce Taylor, Andreas Rosland

Facilitate research, promote education and support the conservation
of the natural and cultural resources associated
with the cenotes and underground rivers of Quintana Roo, México