



Reserva de la Biosfera de Sian Ka'an Cenote Tuun Ja - 19th of October, 2021



I. MISSION OBJECTIVES

On the 19th of October, 2021, members of the Centro Investigador del Sistema Acuifero de Quintana Roo AC (CINDAQ), and the Comisión Nacional De Áreas Naturales Protegidas (CONANP) in accordance with permit CNANP-000-008 (issued on the 13th of September, 2021), flew by helicopter from the village of Muyil to the Zona Nucleo of the Sian Ka'an Biosphere Reserve with two main objectives.

I.1. Initial Dive in Cenote Tuun Ja

One of the primary objectives of our helicopter reconnaissance on the 26th of February, 2021, was to assess whether it would be possible to land a helicopter close to Cenote Tuun Ja. Previous flights over the area by light aircraft and study of satellite imagery had indicated that there was a small clearing to the north of the cenote where this might be possible. We were able to land in February, and also hike to the eastern side of the cenote. We assessed the cenote by free diving and concluded that there was enough reason to return with diving equipment.

We returned to Cenote Tuun Ja on the 19th of October with the following objectives:

1. Perform a reconnaissance dive to confirm the presence of a cave system from Cenote Tuun Ja
2. Fly a DroneDeploy mapping mission over the area
3. Document the area with photographs and video
4. Facilitate CONANP personnel to conduct their own assessments

I.2. Further reconnaissance of the Xamach Fire and Muyil-Caapechén sites

1. Fly over affected forest fire areas to allow CONANP personnel to perform assessment

II. LOGISTICS

II.1. Preparatory work

On the 16th of October, 2021, the CINDAQ team performed camera tests, and reviewed logistics at the helicopter base in Puerto Morelos to ensure optimal image acquisition and safety during the planned flights (**Figure 1**). The position

and fixture of two fixed GoPro8 cameras in the interior, and two GoPro 360° cameras were tested, adjusted and documented to obtain the highest possible number and quality of relevant images for both the forest fire sites and Cenote Tuun Ja. Additionally, the image acquisition setup was dimensioned, both in terms of positioning and power sources, to document the entire flight to the zona nucleo, thus gathering visual information on the route between Muyil and the Zona Nucleo.

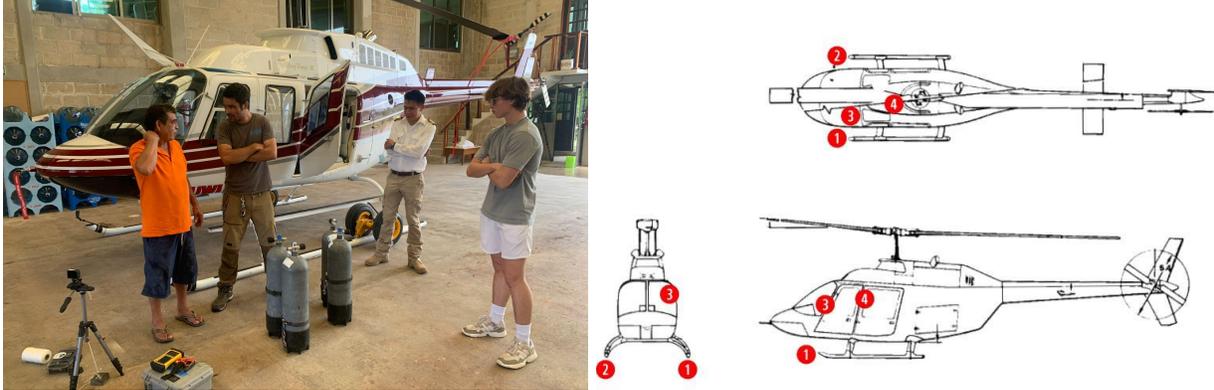


Figure 1: Preparation work and fixed camera position for the helicopter reconnaissance flight

Flight planning, communication, logistics, and safety were reviewed with Pilot Iván Álvarez Vargas. A 38 minute test flight from the helicopter base was flown in order to check camera setup and function, communications, and GPS recording capabilities.

II.2. Helicopter logistics in Sian Ka'an

The planned helicopter-supported project took place on the 19th of October 2021. Below is the logistical plan to move 11 people and the necessary equipment from the village of Muyil to Cenote Tuun Ja.

II.2.1 Participants

- | | | |
|---|--|---|
| <p>• CONANP •</p> <ul style="list-style-type: none"> - Biol. Ángel Omar Ortiz Moreno - Oscar Guzman Escalante - Eulogio Puc Kinil | <p>• CINDAQ •</p> <ul style="list-style-type: none"> - Chris Le Maillot - Fred Devos - Sam Meacham - Julien Fortin - José Luis Hernández - Mauricio Ramos | <p>• GPM Aeroservicios •</p> <ul style="list-style-type: none"> - Iván Álvarez Vargas - Iván Alor Martínez - Juan Patino Ortega (Muyil) |
|---|--|---|

II.2.2 Flights

Two phases of operations were planned for the day.

- Phase 1: Cenote Tuun Ja
- 3 shuttle flights were needed between Muyil and the Cenotes:
 - Flight 1 took 4 people to clear the landing site and light equipment.
 - Flight 2 took 4 people and light equipment.
 - Flight 3 took 2 people and remaining heavier equipment including dive tanks, cooler etc.
- Phase 2: Aerial assessment of the Xamach Fire and Muyil-Caapechén sites
- 1 flight was needed:
 - The helicopter flew the CONANP team over the forest fire sites then returned to Muyil.

II.2.2 Communication & Emergencies

- Sam Meacham, Ángel Omar Ortiz Moreno, Iván Álvarez Vargas, and Juan Patino Ortega used a WhatsApp group to coordinate logistics leading up to and on the 19th of October, 2021.
- Two Garmin inReach units were used for emergency communication and tracking purposes.
- CONANP had radios that allowed us to communicate with the ranger station in Muyil.
- We had a DAN trauma kit, SKEDCO portable stretcher, and emergency oxygen on site.

II.3. Helicopter timeline in Sian Ka'an

This timeline was designed prior to the mission, and followed on the 19th of October, 2021.

- 07h00 -

- Helicopter leaves Puerto Morelos
- GPM Aero truck leaves for Muyil
- CINDAQ team leaves from Puerto Aventuras
- CONANP will be in Muyil

- 07h45 -

Arrival in Muyil

- Put on cameras
- Organize the equipment loads

- 08h15 -

Muyil - Cenotes Zona Núcleo - Muyil

- Passengers
 - Ángel Omar Ortiz Moreno
 - Sam Meacham
 - José Luis Hernández
 - Iván Alor Martínez
- Gear List
 - Garmin inReach
 - Chainsaw/machete/tools/files
 - Repellent
 - First Aid kit
 - Drone Kit
 - Nav Kit, flagging tape
 - Personal packs
 - Water
 - Food/snacks
- Tasks

Enlarge landing area, mark trail to the cenote
Once the area is clear, the helicopter will return to Muyil. Ground support from GPM will return to Muyil on this flight.

- 08h45 -

Muyil – Cenotes Zona Núcleo -Muyil

- Passengers
 - Chris Le Maillot
 - Fred Devos
 - Oscar Guzman Escalante
 - Eulogio Puc Kinil
- Gear List
 - Light gear (Dry suits undergarments)
 - Personal Packs
 - Water
 - Camera Gear

- 09h15 -

Muyil – Cenotes Zona Núcleo

- Passengers
 - Mauricio Ramos
 - Julien Fortin
- Gear List (Heavy Equipment)
 - Whatever remaining gear that is left.
 - Tanks
 - Cooler
 - Garmin inReach
- Tasks

The helicopter will remain on the ground at the cenotes

- 10h00 – 15h00 -

Work on the ground at Cenote Tuun Ja

- Tasks
 - Approx. 2-hour dive by Chris & Sam
 - Drone mapping after the dive
 - Drone video
 - Interviews
 - Surface observations/documentation

- 15h15 -

Cenotes Zona Núcleo – Muyil - Cenotes Zona Núcleo

- Passengers
 - José Luis Hernández
 - Julien Fortin
- Gear List (Heavy Equipment)
 - Dive gear
 - Tanks
 - Cooler
 - Chainsaw/machete/tools
 - Garmin inReach

- 16h30 -

Cenotes Zona Núcleo – Incendio - Muyil

- Passengers
 - Ángel Omar Ortiz Moreno
 - Fred Devos
 - Mauricio Ramos
 - Eulogio Puc Kinil
 - Oscar Guzman Escalante
- Gear List
 - First Aid Trauma
 - Garmin inReach
 - Personal Packs
 - Camera Gear

- 15h45 -

Cenotes Zona Núcleo – Muyil - Cenotes Zona Núcleo

- Passengers
 - Sam Meacham
 - Chris Le Maillot
 - Iván Alor Martínez
- Gear List
 - Whatever remaining gear that is left.
 - Drone Kit
 - Nav Kit

- 17h20 -

Muyil - Puerto Morelos

- Helicopter departs from Muyil to Puerto Morelos

- Flight summary -

Estimated Flight Time (Total 180-200 minutes)

1. Puerto Morelos to Muyil - 45 minutes
2. Muyil – Core Zone – Muyil - 20 minutes
3. Muyil – Core Zone – Muyil - 20 minutes
4. Muyil – Core Zone - 10 minutes
5. Zona Núcleo – Muyil - Zona Núcleo - 20 minutes
6. Zona Núcleo – Muyil - Zona Núcleo - 20 minutes
7. Core Zone – Fire – Muyil – 20 minutes
(contemplating 5 minutes of overflight at the fire site)
8. Muyil – Puerto Morelos – 45 minutes

III. DATA COLLECTION AND OBSERVATIONS

III.1 Cenote Tuun Ja

III.1.1 Surface Work and Documentation

Surface work was limited due to poor weather conditions. It rained almost continuously making drone operations nearly impossible. Additionally, surface filming was also hindered. Despite this, we were still able to accomplish many of the original surface objectives.

The following tasks were completed during the course of the day:

- Videos of all flights were captured on the front skids of the helicopter using GoPro 360 cameras.
- Videos were captured with 2 GoPro 8 cameras installed in the interior of the helicopter.



Figure 2: Ángel Omar Ortiz Moreno (CONANP) and Julien Fortin (CINDAQ) during surface work

- Videos of helicopter and surface operations were captured by Fred Devos with a Sony A7Siii camera.
- High resolution photographs were captured by Mauricio Ramos documenting helicopter and surface operations.
- One short drone flight was performed and images were captured by Mauricio Ramos to document the site and surrounding area from above.
- A small trail was established to access the north side of the cenote.
- A small staging area next to the cenote was established.
- GPS tracks were captured of all of the morning flights using a Garmin eTrex 20 GPS.
- GPS of the landing area, entry point (cave line start) and trail to the cenote were captured using a Trimble R1 GPS receiver alongside the ArcGIS Field Maps app on a Samsung Galaxy A12 phone. All GPS points were averaged a minimum of 200 times.
- The CONANP staff was able to complete a preliminary survey of surface and aquatic features (**Figure 2**), in and around the cenote.

III.1.2 Underwater work

<i>Dive Team:</i>	Christophe Le Maillot (Line), Sam Meacham (Survey)
<i>Dive Time:</i>	120 minutes
<i>Average Depth:</i>	19.1 m
<i>Maximum Depth:</i>	29 m
<i>Halocline Depth:</i>	25m
<i>Total Exploration:</i>	469.1m
<i>Number of Underwater Stations:</i>	34

Table 1: Dive stats for the Tuun Ja dive on the 19th of October, 2021

The dive team used a sidemount equipment configuration with 2 x 85 cubic foot cylinders per diver filled with 40% Nitrox. Both divers used the sidemount, Halcyon RBK rebreather. A 100% 40 cubic foot oxygen cylinder was left at 6m as a precaution.

The time to enter the cave was 60 minutes. The time to exit the cave and survey was 60 minutes. Full profile is available on (**Figure 3**).

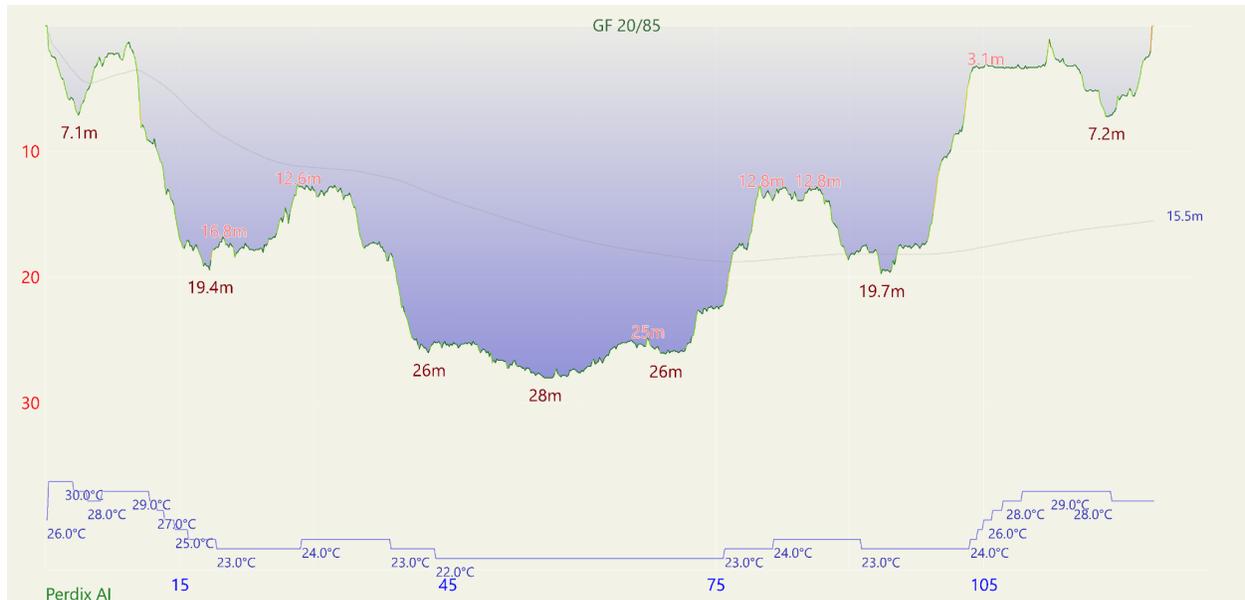


Figure 3: Exploration dive profile in Cenote Tuun Ja, 19th of October, 2021

This was the first dive out of Cenote Tuun Ja, the objective was to do a short, two-hour dive to confirm the presence of cave passageway, and the potential for further exploration.

Tuun Ja is a large (380m x 70m) cenote which is located in the Zona Nucleo of the Sian Ka'an Biosphere Reserve. It is the 2nd cenote in a chain of more than 7 large cenotes running in a west to east orientation (**Figure 4**).



Figure 4: Cenote Tuun Ja and surrounding cenotes, including exploration from Oct. 19, 2021

Our expectations of finding a significant cave were guided by two main factors:

1. The presence of a series of large cenotes in a chain. Generally, the size of the cenotes is a reflection of the cave passageway beneath.
2. Previous exploration from Cenote Boca Paila which has significant cave passage and flow of water coming from the direction of the Zona Nucleo (**Figure 5**).

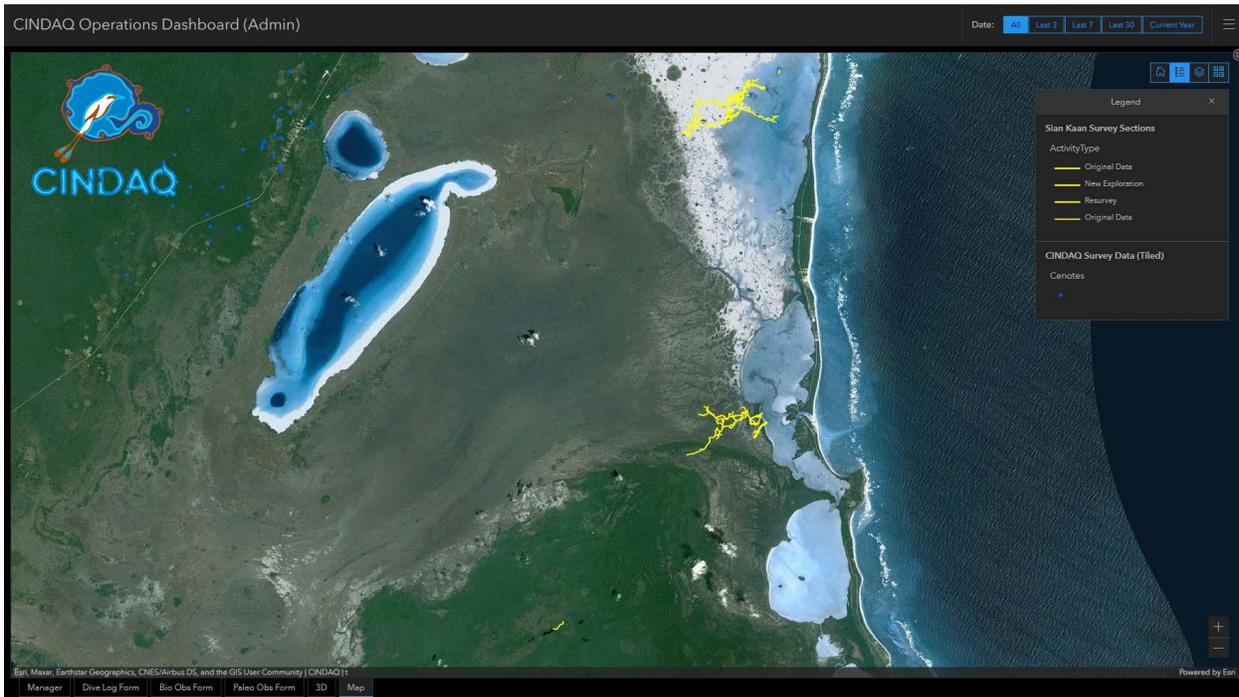


Figure 5: Overview of Cave Exploration in northern Sian Ka'an

The dive team dropped quickly to the shallow northern side of the cenote and followed the rim until hitting the big entrance on the northeast side of the cenote. The cave drops down quickly to 14m, and stays big throughout. Because of its size, it was difficult to distinguish the opposite wall or the ceiling. For this reason, the team followed the north side of the passage which led them to the north, northeast. The center of the main passage is collapsed but the sides are going deeper to about 22m. Speleothems begin at a depth of 18m and were observed in the deeper areas of the cave. At directional marker Peech, the cave depth drops from 18m to 25m and below. There was tannic water above 14m, and a halocline at 25m. The end of the line is open with leads continuing northwest, north, and northeast. There is an interesting lead to the southwest with what seemed to be a defined tunnel at about 30-32m depth.

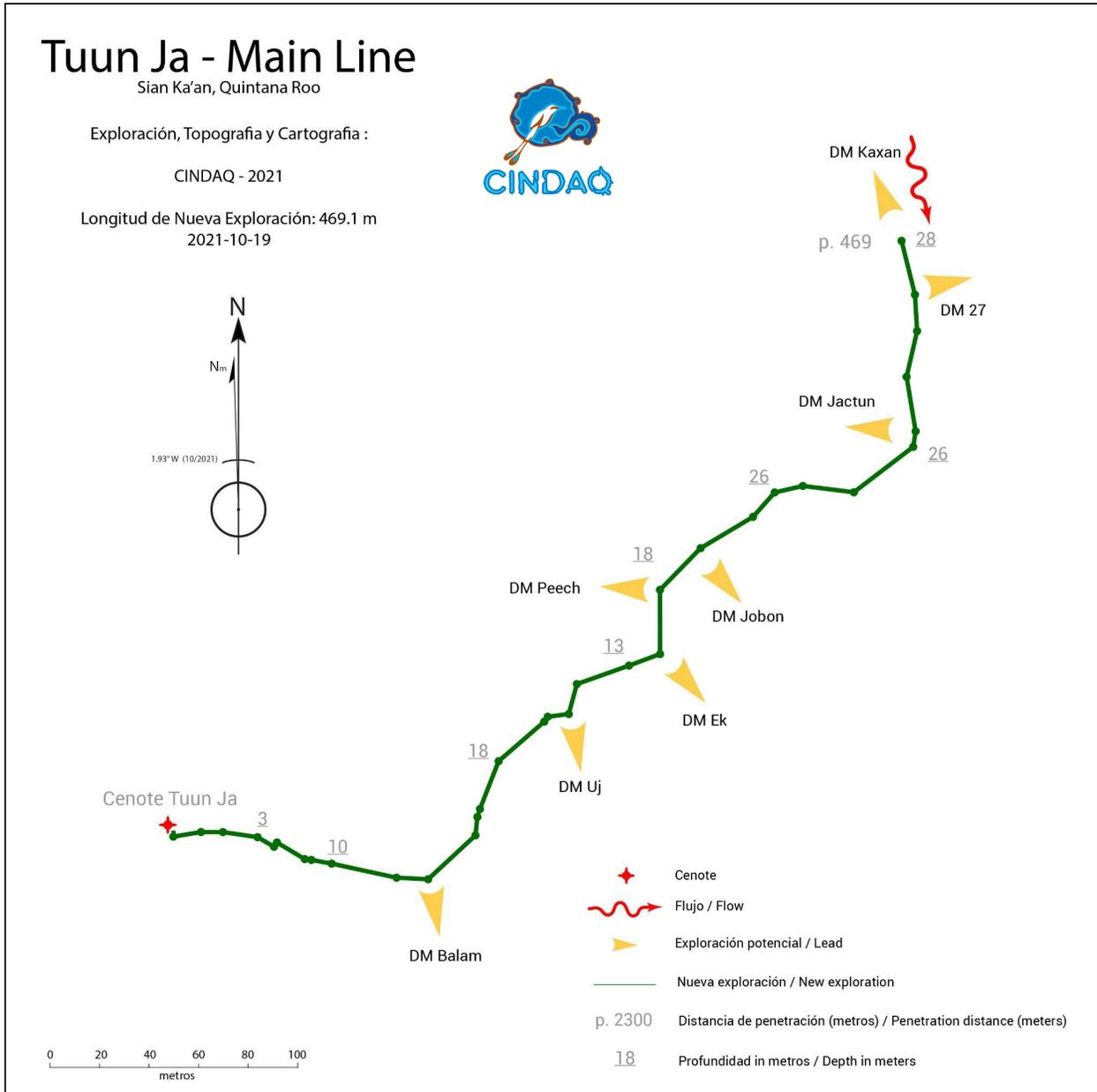


Figure 6: Exploration map of Tuun Ja, as of the 19th of October, 2021

Cave survey was done going out of the cave using a Mnemo cave survey device to measure depth, distance and azimuth. Comments were written down on waterproof paper and tied into the survey later on Ariane Cave Mapping Software. Potential leads (where the cave may continue) were marked using directional marker (DM) arrows. Each DM has a unique name written on it to provide easy reference. Almost every station has a non-directional marker

(NDM) to provide additional orientation for divers in any followup work (**Figure 6**). NDMs were marked in sequential order from RBSK₁, RBSK₂, RBSK_n, etc.

The two main observations that were surprising to the team (**Figure 7**) were:

1. No biology was observed in the overhead cave environment.
2. The water temperature was noticeably colder than any other cave we have dived in this region. At 29m the temperature was 21.7C. The normal temperature range for these caves is between 25-27C.



Figure 7: Chris Le Maillot and Samuel Meacham after the exploration dive

Additional observations:

1. Plenty of surface life in the cenotes (morelet crocodiles, cichlids, tarpon, freshwater fish species).
2. Very organic bottom sediments going east/north east from the cenote in the main passageway.
3. At Non Directional Marker 23, sediment color changes from dark organic to lighter silt.
4. At Directional Marker Peech, speleothems are present and continue from there into the cave. Prior to this the cave passage is a large collapse.
5. The cave has larger than normal passageways in the deeper (25-30m) sections.
6. We conservatively estimate the wall to wall distance in the main passageway to be 20-50m. This was difficult to determine given the passage size.
7. At the end of the line (Directional Marker Kaxan) there is flow from the north in the salt water section (salt water flow is usually observed in an opposite direction to the fresh water flow).
8. Percolation of 'biomats' was experienced in the main passageway.
9. Bacterial growth (biomats) on the floor and walls of the cave was observed.
10. The rocks below the sediment tend to be white in color. This was already observed in Boca Paila.
11. There is an abundant layering of fossilized shells at the entrance of the cave.

III.2 Muyil-Xamach Forest Fire Site Overflight

After the conclusion of diving operations, 5 people and all dive gear were flown back to Muyil on 2 flights. Upon returning to Cenote Tuun Ja, the remaining passengers boarded the helicopter, and an overflight was done down to the Vigia Chica road and then back to the Xamach-Muyil fire site and then on to the Muyil-Caapechén fire site further to the north.

Flight Duration: 25 minutes

The following documentation was done:

- Videos of the entire flight were captured on the front skids of the helicopter using GoPro 360 cameras.
- A Georeferenced 360 video from the left side of the helicopter was produced.
- Videos were captured with 2 GoPro 8 cameras installed in the interior of the helicopter.
- Video of the flight operation was captured by Fred Devos with the Sony A7Siii camera.
- High resolution photographs were captured by Mauricio Ramos documenting the flight and surface conditions.
- GPS track of the entire flight was recorded.

CONANP personnel were able to fly over and assess the damage done by forest fires and subsequent regeneration of these sites (**Figure 8**). Due to poor weather conditions and time constraints, the helicopter was unable to land.

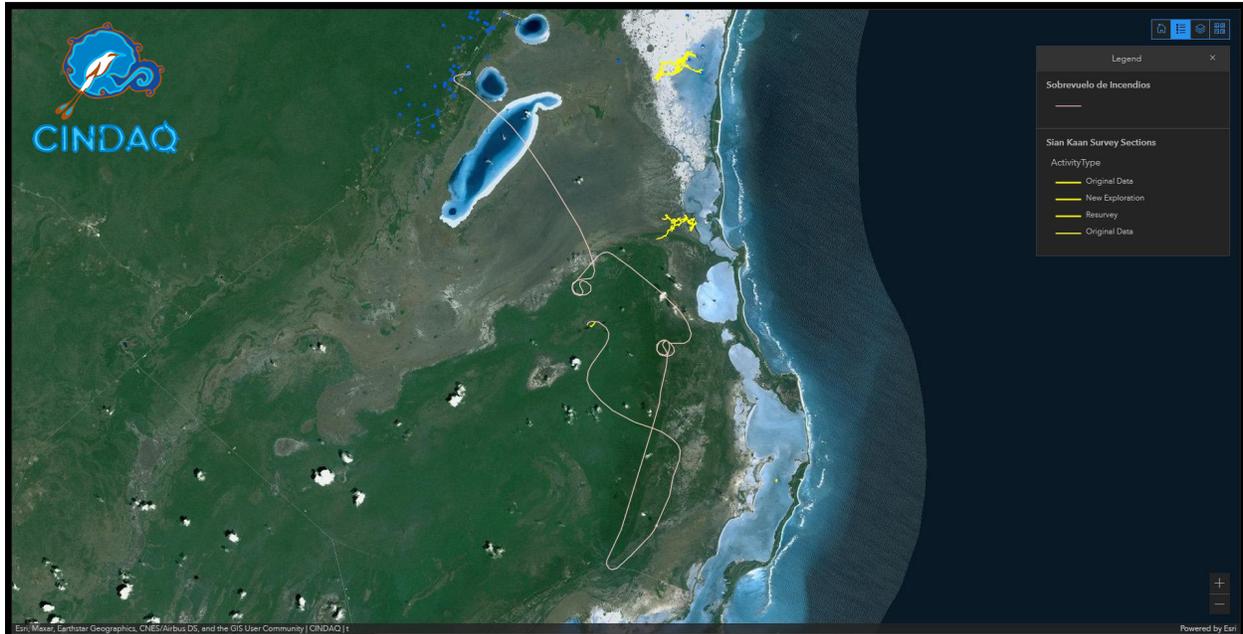


Figure 8: Helicopter Overflights of Forest Fire Areas

III.3. List of media collected

Table 2 summarizes the data collected during the Helicopter reconnaissance on the 19th of October, 2021.

Area	Description	Format
Cenote Tuun Ja	GIS data (helicopter flight tracks, path to cenote, landing site)	kmz,shp
Cenote Tuun Ja	Cave Survey Data (line data, depths, comments)	tmlu, kmz, shp
Cenote Tuun Ja	Photographs by the acclaimed photographer Mauricio Ramos and the CINDAQ team	jpeg, tiff
Cenote Tuun Ja	Videos	mov/mp4
Cenote Tuun Ja	Dive Computer Data (depth, time, temperature)	csv
Over Flight	GIS data (helicopter flight tracks}	kmz, shp
Over Flight	Georeferenced GoPro Max 360 videos from right skid	mov/mp4
All helicopter flights	Full 360° video of all flights (left and right skids 5.6k), GoPro 8 footage from interior of helicopter of all flights	mov/mp4

Table 2: Data collected by the CINDAQ team on the 19th of October 2021

IV. RECOMMENDATIONS & FOLLOW UP FOR CENOTE TUUN JA

Once again, CINDAQ is very pleased to have had the opportunity to do this work for the bioserve. We are happy to continue to contribute our time and resources to the bioserve in order to:

1. Establish a semi-permanent base camp infrastructure that respects the sensitive nature of the Zona Nucleo, but allows for future study and monitoring of this important site.
2. Establish a trail system, in accordance with CONANP's guidance, between the major surface features (cenotes, aguadas, xiitals) so that they can be better studied, monitored and protected.

3. Continue and expand the exploration of the submerged cave system from Cenote Tuun Ja and the surrounding area..
4. Develop scientific objectives to:
 - a. Further study the hydrology
 - b. Further study of the water chemistry and quality
 - c. Further study of the cave and surface biology
 - d. Further study of the environmental record contained in cenote and cave sediments
5. Document the cave with high resolution videos and photographs.
6. Document surface features with DroneDeploy software.
7. Raise awareness locally, nationally and internationally about the Sian Ka'an Biosphere and the threats from development that it faces.

V. ACKNOWLEDGEMENTS

CINDAQ wishes to thank the community of Muyil who provided access to their baseball field as a landing site, and the following institutions and individuals who provided their time and resources to ensure our safety for this project.

- Felipe Cen Canul, Delegado Municipal en Muyil, Municipio Felipe Carrillo Puerto
- Ángel Sulub Hernández, coordinador de Protección Civil en el Municipio de Felipe Carrillo Puerto
- Martín Saucedo Avilés, Moisés Perera Escalante, Jose Vladimir Montalvo Ibarra, Zacarias Pech Witzil, de Protección Civil en el Municipio de Felipe Carrillo Puerto
- Eduardo Chaires Montesinos, Joaquín Díaz Quijano, Arseño Hoil Luna, CONANP, La Reserva de la Biosfera de Sian Ka'an

Ongoing research is conducted under the auspices of the Comisión Nacional de Áreas Naturales Protegidas (CONANP), Dirección Reserva de la Biosfera Sian Ka'an, and in accordance with permit CNANP-000-008, and under the direction and with the cooperation of Biologo Ángel Omar Ortiz Moreno, Director of the Sian Ka'an Biosphere Reserve.

We also acknowledge the entire helicopter crew of ToFly7, Cap. Iván Álvarez Vargas, Iván Alor Martínez, Juan Patino Ortega.

Support for CINDAQ has been generously provided by past and present donors, especially by Dr. Robert Lourie, Rami Shakarchi, Joyce and Lester Coleman, The Mayakoba Classic/Tequila Patron, The Strauss Family Foundation, Rick Guerin, and Michael Ortiz (in memory of Tom Ellis). We are grateful for the support of the Friends of Mexican Development Foundation. We wish to thank the following individuals and entities for their invaluable contribution to our efforts: DroneDeploy, Dr. Wetherbee Dorshow (Earth Analytic Inc), Daniel Ponce-Taylor (CINDAQ AC), Matteo Meacham, Zero Gravity Dive Center, Halcyon Mfg., and SUEX.