Appendix

SAC-TUN Environmental Strategy 2019-2022: Leading by example in environmental and social sustainability

SAC-TUN Environmental Strategy 2019-2022: Leading by example in environmental and social sustainability

Commitment and actions above and beyond our operations

Driven by the imperative challenges of global climate change, the need to augment efforts and investments to protect biodiversity, and our commitment to social responsibility, in 2019, SAC-TUN initiated an independent external evaluation to assess our practices and explore new avenues for sustainability initiatives. Drawing on this evaluation and our decades-long operational experience, and with the aid of our partners from local governmental bodies, civil society organizations and academic institutions, in 2019 we crafted the first phase (2019-2022) of SAC-TUN Environmental Strategy, which has been lauded by as an exemplary model for businesses in Mexico.

Our Environmental Strategy revolves around a Sustainability Model comprising three core pillars: ethical performance in operations, employee integrity, and conservation of the environment alongside comprehensive community development. This model seamlessly integrates into every facet of our operations, aligning with our corporate environmental, social and governance strategy while prioritizing local needs and concerns.

The first three-year phase of our Environmental Strategy, launched in 2019, encapsulated four key initiatives:

- We bolstered our conservation efforts by rehabilitating and reforesting quarried areas, benefitting local wildlife.

- We committed ourselves to supporting scientific research and conservation endeavors, focusing on the Mesoamerican Reef - the world's second most important coral reef barrier.

- We implemented measures to safeguard the fauna and flora affected by new quarrying activities, setting aside forested regions as wildlife corridors to facilitate the movement of wildlife, including jaguars and pumas.

- We expanded our scope of environmental education, cultural initiatives, scientific research, and voluntary projects, aiming to further foster sustainable communities and encouraging active participation from our neighbors in preserving the federal and state protected areas of the Yucatan Peninsula.

Recognizing the pivotal role of protected areas in biodiversity conservation, our support for scientific research and conservation concentrates on Quintana Roo. Here, we have collaborated closely with CONANP (National Commission of Natural Protected Areas) and Quintana Roo's Secretariat of Ecology and Environment (SEMA), endorsing the six objectives outlined in CONANP's framework management plan. Together with esteemed partners such as Amigos de Sian Ka'an, Community and Biodiversity, Pronatura Yucatan Peninsula, AC, the Autonomous University of Querétaro, and the College of the South Border-Chetumal (ECOSUR-Chetumal), we identified four priority areas. These encompass:

- Safeguarding emblematic species such as jaguars, manatees, whale sharks, and marine turtles.
- Conserving priority ecosystems.
- Developing sustainable communities.
- Strengthening management programs for key protected areas.

A pivotal element of our Environmental Strategy is our commitment to active collaboration with partners and local communities, fostering collective efforts in the implementation of these projects. Our first and second years of support have yielded significant results, detailed in our previously published annual SAC-TUN Sustainability Reports (SAC-TUN Sustainability Report 2020 and *https://sactun.com/wp-content/uploads/2023/02/Informe-de-sustentabilidad-2021.pdf).*

The achievements of these first three years are described in detail below.

ACHIEVEMENTS IN THE THIRD YEAR (2022) OF THE FIRST PHASE (2019-2022) OF THE ENVIRONMENTAL STRATEGY

DEVELOPMENT OF A COASTAL POLICY FOR THE STATE OF QUINTANA ROO[1]

In one of the most important projects in phase I of our Environmental Strategy, SAC-TUN supported state and national authorities, civil society organizations, and other actors to develop a state coastal policy for Quintana Roo, *http://po.segob.qroo.gob.mx/sitiopo/MicroPO.php Text to search: Coastal Policy of the State of Quintana Roo; Date: 2022-08-26; Publication Type: Extraordinary; Period: Ninth*

Quintana Roo's economy depends in greater proportion on its coast and on the environmental services that its natural resources provide than any other state in Mexico. This increases the importance of implementing governance strategies and methods that allow the state's desired sustainable development objectives to be achieved.

The Quintana Roo Coastal Policy was led by the SEMA and was designed with the collaboration of more than 50 specialists from scientific research institutions, civil society organizations and different state and federal agencies who met in two workshops during 2021. The document highlights the interconnections between the state's inhabitants, geology, soil, cenotes, caves, the atmospheric water cycle, underground hydrological structures and the Caribbean Sea, recognizing the interdependence between nature and people.

The first workshop conducted an integrated diagnosis of the coastal zone's strengths, opportunities, weaknesses, and threats. The second was to design the strategic lines and choose the data to be included in the final report.

The final coastal policy document contains a detailed snapshot of Quintana Roo's many and diverse coastal ecosystems, as well as fundamentally important socio-economic, demographic and vulnerability considerations, and describes its three overall objectives to:

1. Contribute to improving the living conditions of the coastal populations of Quintana Roo through productive diversification and the sustainable use of natural resources in an integral and equitable development framework with social participation and recognition of indigenous peoples.

2. Strengthen the local economy through the promotion of a circular model, improve regional and national competitivity, and promote institutional concurrence in coordination with other actors and encouraging responsible economic and productive activities based on marine and coastal environmental resources.

3. Evaluate maintaining and restoring the ecosystem services of the coastal zone of Quintana Roo through innovation and the application of technical, legal and economic instruments for the conservation of biodiversity and its natural elements, promoting its resilience and regional and international cooperation.

The state coastal policy document was published in September 2022 and offers detailed strategies and yearly lines of action towards achieving these objectives.

Quintana Roo's idyllic coast is the main pillar of our economy, providing a source of livelihoods for our ever-growing population by attracting hundreds of thousands of tourists each year, and supporting a commercial, sport and subsistence fishing industries.

However, our coastal environments are at risk, both from major meteorological events and climate change, and from unregulated anthropogenic pressure from the booming tourism industry which has affected the continuity and connectivity of natural land ecosystems.

Quintana Roo's development plans contemplate the construction of thousands of hotel rooms and private residences in the coastal area, which will significantly increase the number of tourists who visit us. This will be accompanied by the construction of more roads, drainage systems, electrical installations and other infrastructure, all of which will require careful planning to minimize the impact on coastal ecosystems.

The adoption of a state coastal policy will contribute to balancing the growth of towns and cities with full respect and care for the environment and existing legal provisions. It creates the framework for establishing dynamic, flexible, and consistent planning and regulation instruments and for incorporating strategic urban planning programs that will improve basic public services and stimulate the economy through sustainable tourism and fisheries that consider the benefits that restoring, conserving and sustaining our natural ecosystems can provide for future productive and leisure activities of the area, in this way generating sustainable livelihoods for more of Yucatan's residents.

[1]This project replaces the 2019 proposal to develop the Majahual wetlands into a national protected area, which preliminary studies showed to be unviable.

JAGUAR (*PANTHERA ONCA*) HABITAT AND MOVEMENTS IN A HUMAN-DOMINATED LANDSCAPE IN THE YUCATAN PENINSULA, 2019-2022

For the last four years, SAC-TUN has been supporting the Autonomous University of Queretaro in monitoring jaguar and other feline movements across different landscapes in and around Playa del Carmen, Quintana Roo.

One of the principal goals of this project was to contribute and strengthen knowledge about the jaguars' and other felines' use of developing and fragmented landscapes by capturing and placing satellite transmitter collars on up to 5 jaguars on SAC-TUN properties.

Camera traps

To find out which areas the felines preferred to frequent, between 2019-2022 we placed a total of 32 camera traps on the SAC-TUN properties and created a database georeferencing all the wildlife photographed in this period.

From photographs, we identified the individual spot patterns of 15 jaguars (6 females, 7 males and 2 undetermined) in the SAC-TUN properties: 1 female jaguar in 2019 plus 1 jaguar sex undetermined; 2 females (1 new) and 2 new males in 2020; 6 females (4 new), 3 new males and 1 jaguar sex undetermined in 2021; and 3 females (1 new) and 4 males (1 new) in 2022. Two of the male jaguars identified in 2021 are the grown cubs of the first female identified in 2019.
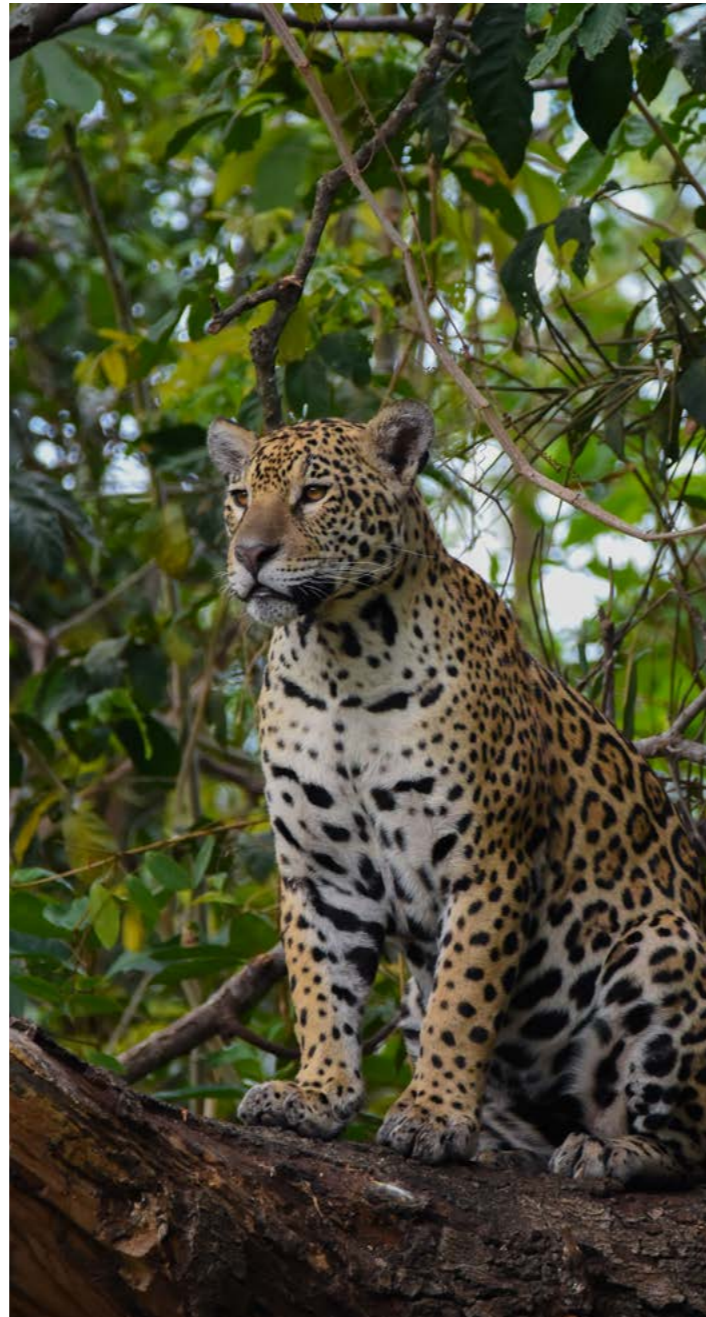
Over the study period, our cameras have taken a total of 68,537 photographs in the SAC-TUN properties (6,116 in 2019; 16,296 in 2020; 17,906 in 2021; and 28,219 in 2022) showing the presence of 160 species of vertebrates, including 79 species of birds, 31 mammals, 16 reptiles and one amphibian, 29 under some category of protection by Mexican law. Seven jaguars (3 females and 4 males) were photographed in 2022.

Of the photographs taken between April and December 2022, 11 species are registered as at risk in some way under Mexico's NOM-059, and 6 appear on IUCN's Red List of Endagered Animals. Many of these species are among the least photographed of animals but their very presence in SAC-TUN properties implies that they find adequate conditions there for their survival. This information will be useful in the future for devising strategies for their conservation.

The most photographed were white-nosed coati (*Nasua narica*), gray fox (*Urocyon cinereoargenteus*), ocellated turkey (*Meleagris ocellata*), white-tailed deer (*Odocoileus virginianus*), cereque or agouti (*Dasyprocta punctata*) and opossum (*Didelphis virginiana*) - all of which, apart from the turkey and opossum, serve as prey for jaguars and pumas and are well dispersed and represented across the SAC-TUN properties, which may be what attracts these large felines to this area. The least photographed reptiles were green and gray iguanas.

For comparative analysis of wildlife numbers on privately owned properties, in October 2019 and 2020 we also installed 23 camera traps on the Ejido Manuel Antonio Ay located 11 km away in the municipality of Tulum. The camera traps remained active for a month on each occasion and recorded photographs of 2 jaguars and an overall total of 38 species (16 mammals, 3 reptiles and 19 birds).

Capturing, tagging and releasing

Based on the photographic evidence provided by the cameras, on four different occasions between December 2019 and December 2022 we deployed traps at preselected points on the SAC-TUN properties for the purposes of capturing, examining, tagging and releasing jaguars and other felines for monitoring. The six most recent traps were deployed in November 2022 and remained open at the time of this report in the hope of recapturing already tagged felines and replacing the worn-out batteries of their radio collars.

In all, a total of 7 felines were tagged and released over the three-year study period: 1 male and 1 pregnant female jaguar in 2019, 2 male and 1 female puma in 2020, 1 female jaguar and 1 male puma captured between January and March 2022, and 1 puma recaptured in December 2022.

The felines were anaesthetized and physically examined by a veterinarian to determine their state of health, and blood and other tissue samples taken for further analysis. Results from 2019-2020 showed that one male and one female puma were young, around 17 months old, with the male thin and the female in a poor state of health. Judging by the state of their teeth, the other male puma and the pregnant female jaguar were aged around 5 years. The male jaguar was oldest, at 7 years of age. The 3 pumas presented with, and were treated for, the *Dirofilaria* sp. parasite, commonly known as heartworm.

Of the 2 felines caught in February 2022, the 2-year-old female puma was in excellent health but too small for the satellite collar and so was examined but released without tagging. The male puma that was captured a few days later was also in good health and of a similar age but slightly larger and so was fitted with a satellite collar and released. No new felines were captured during the second trapping period in 2020-2021. In the third trapping period in December 2022, a previously tagged puma was recaught and the data from its radio collar downloaded for later analysis.

Based on our experiences throughout the duration of this project, we have ordered a modified radio transmitter collar attachment for use with smaller jaguars and bought five new radio transmitters, two of weasel size and 3 for ocelot.

## Assessing jaguar habitat use, prey and conservation requirements

More than twelve months of satellite monitoring between 2019 and 2020 of the first five tagged felines' movements (1 female and 1 male jaguar and 1 female and 2 male pumas), together with 8 months of satellite monitoring of the puma tagged in 2022 and the data recuperated from the radio-collar of the jaguar that died in 2021, have provided us with 2,503 locations which we used as a baseline to create a preliminary map of feline roaming areas. In all, these tagged felines actively ranged a total area of 544 km^2 between Playa del Carmen and Akumal, with male felines tending to roam wider areas than females.

Signals from the radio collar of the male puma that was tagged in February 2022, together with more locations obtained from the movements of the 2 male pumas recaptured in December 2022, have enabled us to expand our preliminary map of the total area of land roamed by the felines overall.

Our updated map shows the home range of each animal (the area within which an individual moves to acquire resources that increase their survival) as well as identify other areas that they used less frequently as temporary or transit zones.

Analysis of roaming data shows that the activity and movement of big cats is influenced by the availability of resources that generally change depending on the time of year and season. Overall, most of the felines ranged further during the dry season of both years, although the female jaguar ranged further in the rainy season of 2020 when she crossed highway 307 for the first and only time. Her range reduced considerably to just 2.31 km^2 in February 2021 and it is likely that this area of SAC-TUN properties is the probable location of the burrow where she gave birth to 2 cubs that were photographed by the camera traps in August 2021. These cubs are now over two years old and were photographed in 2022 roaming the same area where they were born.

Although the transmitters of the first 5 tagged felines are no longer active, we have photographic records showing that 1 male puma was alive in November 2022 and 1 female puma was alive in March 2022 when she was seen accompanied by her less than six-month-old cub.
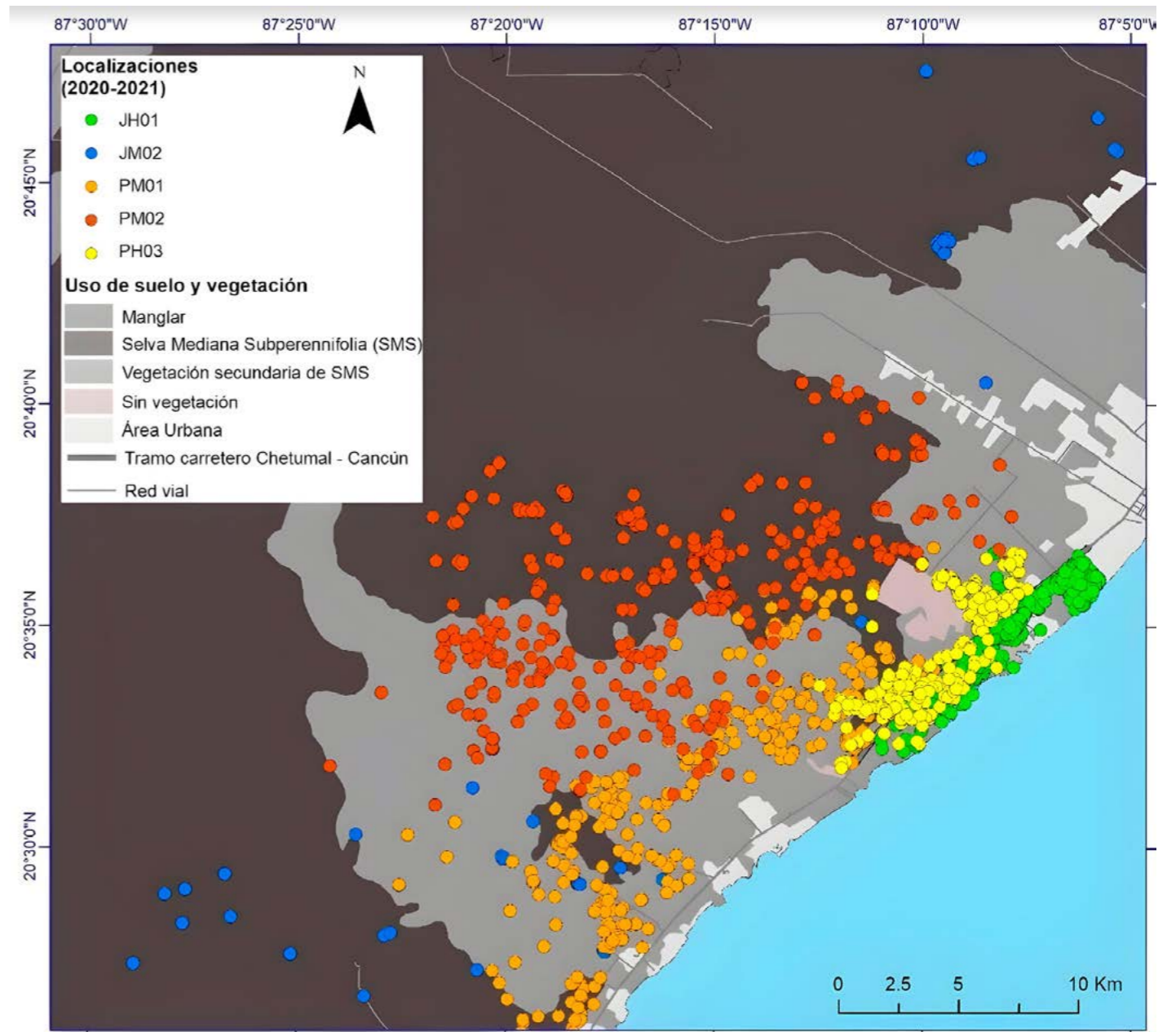
Type of habitat

Most of the study area is covered with medium subevergreen forest up to 22 metres tall. However, most of the locations frequented by the felines show secondary subevergreen vegetation and, to a lesser extent, mangrove swamps, under 19 metres in height, and some areas without vegetation.

Jaguar/human conflict

Our maps of large feline movements have been particularly useful in clarifying the difficulties animals are increasingly facing crossing federal highway 307 as traffic and other human activities increase in the area. Two big cats were run over almost 10 km south of the Playacar border: the first roadkill was recorded on 3 June 2021 of a male puma without a radio transmitter; the second was the death of the adult female jaguar that we first captured and tagged in 2020 and which gave birth to two cubs and which we followed for a year and a half. She was run over on highway 307 on 30 September 2022, just 160 metres north of the first roadkill. We have recovered her satellite transmitter and are currently analysing the stored information to decipher her previous interactions with highway 307. This information will provide useful data about other crossing sites for wildlife on highway 307. In the coming months, we plan to initiate a proposal for an exact site for the construction of a dedicated wildlife passage to mitigate the risk of more felines and other wildlife being run over on this highway.

Fecal samples

Extraction of DNA from intestinal cells found in faecal samples is a non-invasive method of determining the presence and sex of different wildlife species within a study area. We made a genetic analysis of the faecal samples taken within SAC-TUN properties between 2018-2022 and from these determined the presence of different numbers of jaguars, pumas and other wildlife frequenting SAC-TUN properties each year. The most recent examination of 40 faecal samples collected up to September 2022 indicated the presence of 10 jaguars (3 females and 7 males of which 1 male and 1 female jaguar were half siblings), 6 pumas (1 female and 5 males), 3 ocelots (1 female and 2 males), 26 Yucatan brown brocket deer (*Mazama pandora*) and 25 white-tailed deer (*O. virgianus*).

Dietary analysis of feline faecal samples (5 jaguars, 2 pumas and 2 ocelots) collected over the total study period revealed the presence of 8 species of prey (six mammals and two reptiles) that these felines fed on. The most abundant prey species were cereque or agouti (*Dasyprocta punctata*) and white-tailed deer, followed by pizote or coatimundi (*Nasua narica*). The least abundant prey species were iguanas (*Iguana iguana*), lowland paca (*Cuniculus paca*), collared peccary (*Dicotyles tajacu*) and gray fox (*Urocyon cinereoargenteus*). Faecal samples from jaguars showed traces of coatimundi, gray fox, white-tailed deer, green iguana, agouti, and collared peccary (*Dicotyles tajacu*).

The presence of 26 individuals of brown brocket and 25 individuals of white-tailed deer, with both species demonstrating high genetic diversity, may be due to their habitat being located on privately-owned SAC-TUN properties where hunting and other deleterious activities are prohibited, so maintaining an effective herd size. The results were especially noteworthy for brown brocket deer which are considered endemic to Yucatan and it was not expected to find such high genetic diversity within the SAC-TUN properties. This suggests that this species may be more resilient and adaptable than was previously thought.

International scientific publications

As a result of our project, three articles have been published in peer-review journals:

•Female puma (*Puma concolor*) highway crossings in the Yucatan Peninsula.
https://scholarsarchive.byu.edu/wnan/vol80/iss4/19

•Coyote recent expansion in Quintana Roo state, NE Yucatan Peninsula, Mexico.
Coyote recent expansion in Quintana Roo State, Northeast Yucatan Peninsula, Mexico (reabic.net)

•Genetic diversity between *Odocoileus virginianus and Mazama pandora* in northeastern Quintana Roo.

Challenges and lessons learned

We continue to be challenged by the ongoing thefts of cameras from SAC-TUN properties. In 2022, three cameras were stolen in the Pueblito area, even though two of them were placed inside metal cages for protection from the unknown persons who enter the properties uninvited, possibly for hunting purposes. Extra cameras were installed to compensate for their loss.

CONSERVATION STATUS OF THE MANATEE POPULATION IN QUINTANA ROO AND THE CONNECTIVITY OF THE POPULATIONS IN THE COASTAL ZONE, 2019–2022

The principal goals of the first phase of this project led by ECOSUR-Chetumal were to:

•Establish the baseline of spatial distribution, abundance, and movements of manatees on the coast to establish mechanisms for regulating and mitigating the threats detected.

•Know the demographic and genetic structure of the manatee population and its connectivity.

•Contribute information to Mexico's Action Program for the Conservation of Species: Manatee (*Trichechus sp*.) and to the IUCN Red Book.

•Develop a technical report for the protected areas in which we work, with information on the status of the population in the area, identified threats and protection recommendations.

To establish the baseline, we conducted aerial censuses in 2019 and 2022; used observations, photos and videos to identify individual manatees; and tracked the animals' movements using data from attached radio transmitters.

Aerial census

From 11-13 November 2022, we conducted an aerial census covering Holbox to the north, passing through the Sian Ka'an Biosphere Reserve (RBSK) in the centre of the state with its two bays, Ascensión and Espíritu Santo, to Xcalak and the Chetumal Bay Manatee Sanctuary in southern Quintana Roo. These followed a similar route to our aerial surveys of 2019.

During the November 2022 census, we counted 184 manatees of which 88.6% were adults and 11.4% calves. This was a higher total number of manatees and a higher proportion of pups than was counted in the 2019 census, which represent a reproductively healthy population.

For the first time, in 2022 both adult and calf manatees were found to be most abundant in the RSBK (71% of which 114 adults and 16 calves), with Ascensión Bay having more than half of the specimens, followed by Chetumal Bay (27% with 44 adults and 5 calves). In 2019, just 32% were concentrated in (RBSK). In Holbox in the Yum Balam region, 5 adult manatees were counted in 2022, a few more individuals than in 2019 but no calves were observed, unlike the 2019 census. For Xcalak, 3 adults were counted in 2019 but none were observed in 2022.

The decrease in manatee numbers in Chetumal Bay could be explained by a movement of individuals north towards Belize, since we have evidence that 4 of the 6 manatees marked in Chetumal Bay in May 2022 crossed into Belize and remained there for 46% of the time after they were marked. This movement of manatees along the coast is one reason why it is important for us to work together with Belize in making efforts to carry out a joint and simultaneous aerial census to be able to identify more accurately manatee abundances across the region. Unfortunately, our census in coordination with Belize that was planned for May 2022 was postponed.

The movement of manatees northward over the coastal zone would also be a possible explanation for the significant increase in numbers of manatees in the RBSK. In favour of this hypothesis, we also have the total of 105 sightings of manatees registered by volunteers observing the coastal strip between Mahahual and Xcalak (see below), several of which had scars from injuries or mutilations by boat propellers, which the scientific evidence indicates is an alarming problem in Belize. To confirm and evaluate this hypothesis, we would like to use drones and light aircraft to make a special photo identification effort in the RBSK.

Photo and video identification

We had a very positive and fruitful experience collaborating with dive houses, professional guides, boat captains and volunteer students, using their photographs and videos to identify and monitor manatees in Mahahual-Xcalak on the southern coast of the Mexican Caribbean.

In the first phase of this citizen science collaborative programme, between February and October 2022, they recorded 105 manatees (41 males and 19 females) in photographs and videos which allowed us to observe part of their behaviour. From these, we identified 60 individuals by their natural markings and by scars and mutilations: 13 of these manatees had non-recent cuts caused by the boat propellers, including one with a caved-in spine which we assume was the result of being hit by a boat. These results, together with the increase in manatee accidents with boats reported in Belize (Galves et al.,2022), indicate the importance of continuing with photo identification monitoring to assess the impact of these accidents on the population and to be able to take measures to prevent them.

Our citizen scientists succeeded in recording, for the first time on video, two mating groups of manatees. Both videos were filmed in transparent waters and offer relevant information that helps us to learn more about the reproductive behaviour of manatees in their natural environment. In the first video, a female was recorded followed by 8 males for 10 minutes before getting lost leaving the reef towards deeper waters. The second video records the rejection behaviour of a female towards two males. Both videos show the competitive attitude between the males and their harassing attitude towards the female which becomes tolerant or rejects them, depending on her phase of reception.

Thanks to these videos and photos donated through this project by professional divers and guides, for the first time we have high-quality film and photographic material for exclusive use in conservation, communication and research activities.

We registered all the photo and video information in a database in which each identified manatee was assigned a unique identifier with relevant information such as coordinates of its location, sex, age, the corresponding photograph and/or video, and its author.

Our citizen science project was very well accepted by our three collaborating diving houses[2], enabling them to participate in advancing the conservation of manatees and their habitats and improve their practices in encounters with marine fauna. Other dive houses from the centre and north of Quintana Roo have expressed interest in similarly participating and, as we have received information on manatee sightings from other parts of the state, it is important to integrate them so that we can acquire more information about the biology and behaviour of manatees along the entire coast of Quintana Roo. This will be a strong complement to information from future aerial counts and radio tagging of manatees.
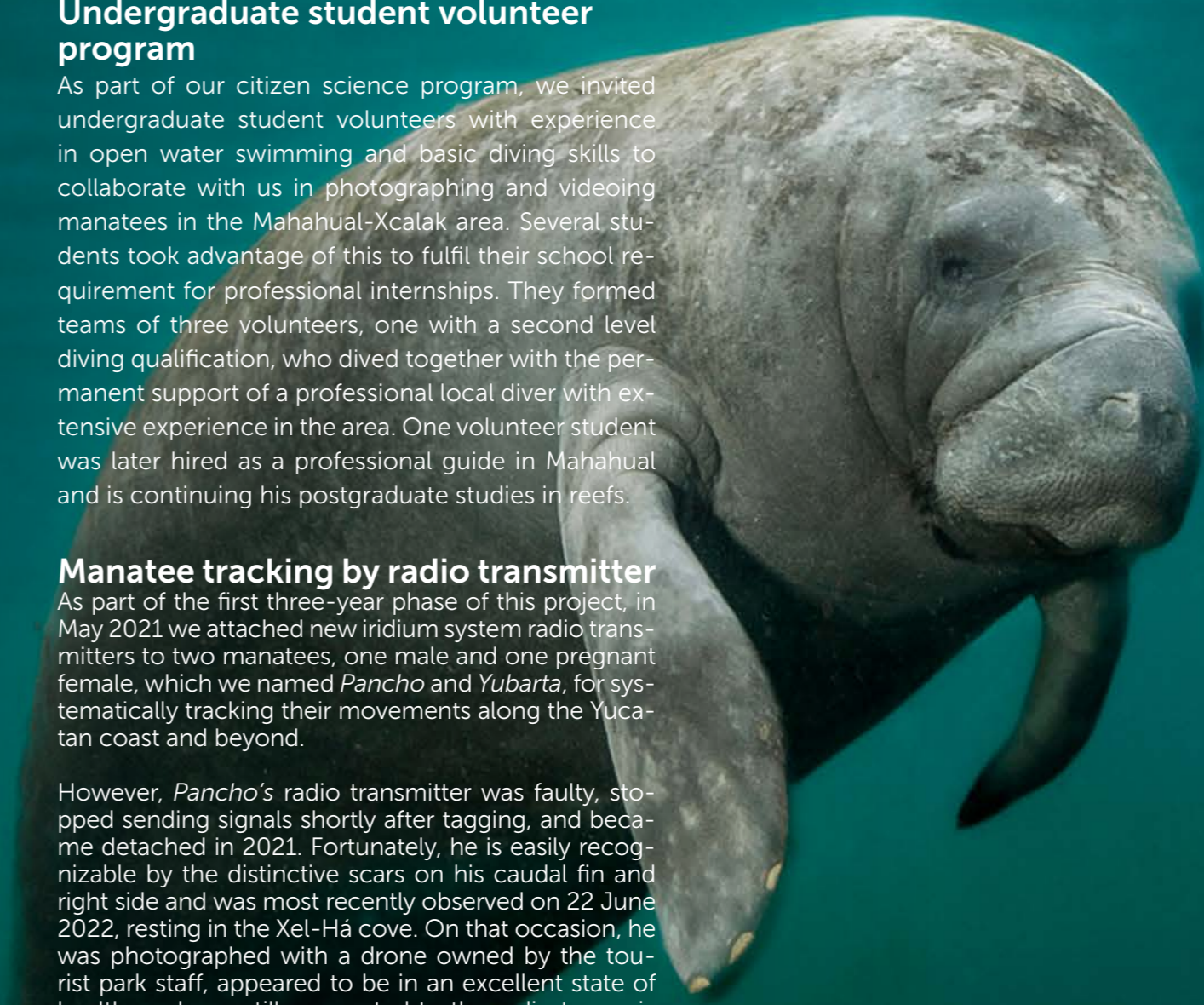
Undergraduate student volunteer program

As part of our citizen science program, we invited undergraduate student volunteers with experience in open water swimming and basic diving skills to collaborate with us in photographing and videoing manatees in the Mahahual-Xcalak area. Several students took advantage of this to fulfil their school requirement for professional internships. They formed teams of three volunteers, one with a second level diving qualification, who dived together with the permanent support of a professional local diver with extensive experience in the area. One volunteer student was later hired as a professional guide in Mahahual and is continuing his postgraduate studies in reefs.

Manatee tracking by radio transmitter

As part of the first three-year phase of this project, in May 2021 we attached new iridium system radio transmitters to two manatees, one male and one pregnant female, which we named *Pancho* and *Yubarta*, for systematically tracking their movements along the Yucatan coast and beyond.

However, *Pancho's* radio transmitter was faulty, stopped sending signals shortly after tagging, and became detached in 2021. Fortunately, he is easily recognizable by the distinctive scars on his caudal fin and right side and was most recently observed on 22 June 2022, resting in the Xel-Há cove. On that occasion, he was photographed with a drone owned by the tourist park staff, appeared to be in an excellent state of health, and was still connected to the radio transmitter belt. We returned *Pancho's* radio transmitter to the manufacturer for diagnosis and installation of new software, and we plan to recapture him to reconnect it so that we can continue to monitor him remotely and, if he decides to return to Florida, follow the route he takes to try to better understand his long-distance migration behaviour. We don't know if *Pancho* is still in Mexican waters, but our observer network continues to watch for any sightings.

Yubarta was observed with a recently born calf in Laguna Guerrero in May 2022 and, in November 2022, we received a video report showing her swimming alongside her calf in Belize, on the shores of the town of Corozal. We were able to track *Yubarta* remotely for longer than *Pancho*, although her radio transmitter also worked only irregularly until signal was lost. We made several attempts to recover the radio belt or change its program remotely to try to repair the problem, but without success, and we anticipate that soon the battery will run out and the radio may become detached, making it hard to recover. However,

with the data sent by the transmitter we created and updated a distribution map showing the movements of *Yubarta* and her calf as well as their preferred resting areas along the coast. Their areas of greatest use were in the north of Tamalcab Island, the area called la barra, the channels and Laguna Guerrero. This is important information and, after several years of monitoring the tagged manatees, we now have sufficient evidence to confirm that Laguna Guerrero and its access channels are one of the core areas of the Bahía de Chetumal Manatee Sanctuary Reserve where manatees choose to shelter. Even in conditions of low water temperatures during the passage of severe cold fronts, this area appears to serve manatees as a temporary refuge[3]. For this reason we need to implement more specific measures to protect this area.

Our plans include trying to locate and tag the other Florida manatee, named *Luna*, that was sighted off the coast of Yucatan a few weeks after *Pancho* was detected and has a monitoring history of more than 1,000 days in Florida (Morales-Vela et al., 2021).

If the problems persist with the Iridium radio transmitters, we may have change to the Argos system. We initially selected the Iridium system for its lower cost of equipment and satellite services and because it offered new program applications.

Capture of manatees for vet examination

When we captured an adult female manatee in May 2021 we detected a papillomatous lesion, indicating papillomavirus infection. It was the first report of the presence of this virus in the region and we were concerned that it may represent an epidemiological risk to the manatee population in our area (Mignucci-Giannoni et al., 2022). Consequently, when we captured six manatees (4 males and 2 females) in June 2022 to obtain body measurements and take biological samples, we invited specialized vets to accompany us specifically to examine the manatees for presence of papillomatous legions or other ailments. Fortunately, none presented evidence of papilloma. Due to the seriousness of this virus, we are implementing a serological analysis that detects the virus in blood so that, over time, we will be able to compare the results with previous analyses and evaluate the incidence of this disease in the Yucatan.

One of the male manatees captured in June 2022 turned out to be a recapture with a subcutaneous chip showing he was originally captured, tagged and released in 2005 in the same area. At that time, he was evaluated as very thin, and it was considered doubtful that he would survive. His recapture in the same area points to the strength of manatees and their fidelity to specific areas. All other manatees captured were in good health.

Genetic analyses

We have received partial results of the genetic analyses of 14 manatee specimens captured in 2021-2022, and of *Pancho.* This work was late in starting because some reagents were delayed in arriving and we expect to complete it in 2023.

Publication of book on manatees

The first book in Mexico promoting the dissemination of scientific knowledge of manatees in the Yucatan Peninsula, Mexico and Latin America has been prepared and is awaiting printing. This book encompasses more than 33 years of technical and scientific research and knowledge, including information obtained as part of this project supported by SAC-TUN. It includes historical stories told by different generations of fishermen on their encounters with manatees, including their hunting techniques, the use they gave to meat, skin and bones, and to the notable decrease in populations perceived by people living in the region who learned over time the value of this resource and who tried to avoid its extinction by changing their hunting practices. Other topics include the threats to manatees from environmental contamination, boat accidents and emerging viral diseases which, over the years and thanks to the support of this project, we have been able to document. The book further highlights the importance of existing protected natural areas in Quintana Roo and gives recommendations for the future conservation of this species.
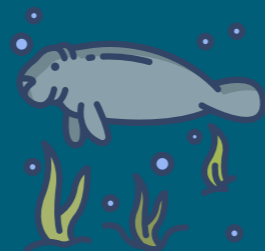
CONTRIBUTION TO THE SUSTAINABLE MANAGEMENT OF WHALE SHARK TOURISM IN THE MEXICAN CARIBBEAN, 2019-2022

The aim of the first phase of this project was to develop models to support sustainable management plans for local tourism in whale shark aggregation areas by offering insight into the number of tourists who can interact with whale sharks at any one time and in any one area without negatively impacting the ability of whale shark populations to thrive in their natural habitats. These types of carrying capacity models are essential both to ensure the conservation and protection of whale shark populations and the sustainability of whale shark tourism in generating local livelihoods for residents.

Aerial overflights to count whale shark aggregations

Between June and September 2019-2022, with the assistance of CONANP personnel from the Mexican Caribbean Biosphere Reserve, we conducted 20 aerial surveys over the whale shark aggregation area in the northern Mexican Caribbean, during which we spent a total of 42 flight hours covering an ocean search area of 5,676 km^2. These flights completed a period of more than six years[4] of continuous and systematic medium-term monitoring during which we recorded a total of 1,025 whale sharks and established that the majority (97%) of whale shark tourism activities take place within 260 km^2 of the Mexican Caribbean Biosphere Reserve, located in the central part of the ocean area known as El Azul.

In the last three seasons (2021-2022), we observed a significant decrease in the number of whale sharks sighted, with only 83 whale sharks recorded during five flights in 2022 - the lowest number of sharks recorded through overflights per season since 2016. A similar decline in sightings has been reported from whale shark aggregation sites in other parts of the world[5].

Monitoring and evaluating compliance with whale shark tourism regulations

An important aspect of phase 1 of our project was to investigate compliance with the established regulations governing whale shark tourism. Since the project started, we have been conducting regular seasonal monitoring activities to evaluate how well tourist boat personnel and visitors comply with these regulations which include, among others, time limits on how many minutes and for how long each tourist is permitted to interact with the sharks, how many boats can be stationed near to each whale shark and how far away both boats and tourists need to keep from each animal.

In 2021-2022, in coordination with the CONANP Mexican Caribbean Biosphere Reserve, we undertook 11 tours aboard the park ranger's boat to assess compliance with the rules during tourist activity. In 2022, the average compliance rate overall was 67% and the rule with the least compliance was the number of people swimming with a whale shark, with only 37%. It was notable that low compliance rates coincide with a high number of tourist vessels and low abundancy of whale sharks. The need to emphasise the importance of, and strengthen compliance with, the established rules is addressed in phase II of this project which began in 2023 (see below).

After analysing all the information generated from 2016-2022, we prepared two comparative sustainable management models. The first was based on the abundance of whale sharks in El Azul and gave us a tourist carrying capacity of 1,051 visitors per day. The abundance of sharks has proven to be a highly relevant variable in carrying capacity calculations, since it can affect the acceptable number of

boats and visitors per day, and also influences compliance with the rules.

The second model was based on the surface area for tourist use in El Azul and gave us a carrying capacity of 965 visitors per day. The use of surface area as a base variable to estimate carrying capacity has the disadvantage that, in any given area, there may not be enough sharks to sustain demand for tourist visits.

The two models differ by 8% in their recommended number of visitors per day. However, for both scenarios, our results suggest that the currently accepted number of visitors per day (120 boats each with 10 passengers) is too high. During 2022, recreational activity with whale sharks took place mostly in the central portion of El Azul, covering just 65% of the total area that was used to calculate our carrying capacities. If only this smaller area is taken into consideration, our carrying capacity could be overestimated, that is, allowing more tourists than the actual area can accommodate.

Another important factor to be taken into consideration is that when tourism management capacities are low, the tourist carrying capacity decreases proportionally. From consultations with staff from the Mexican Caribbean Biosphere Reserve, we estimated that current management capacities for tourist activity with sharks are 70%. Strengthening management and the skills of service providers will involve the need for more personnel and more training, as well as better financing, equipment, materials, vehicles, and a greater and improved dissemination of the regulations for swimming, and the ways in which the activity should be carried out, both to avoid negative impacts on whale sharks, and to avoid generating erroneous expectations of the activity among visitors.

Besides generating the data used to produce the carrying capacity models, the first three-year phase of our project clarified which areas of El Azul are most used for whale shark tourism, that some of the regulations governing tourist interactions with whale sharks are poorly followed, that carrying capacity numbers vary over time depending on the number of whale sharks and the size of the area in which they are sighted, and that whale shark numbers appear to be declining.

So far there are no studies to explain this decrease in sightings in the region or worldwide. The reasons could be diverse, from global oceanic phenomena that cause changes in habitat conditions (temperature, marine currents, stratification, etc.), changes in food availability, bad tourist practices or the consequences of captures to which this species was subjected in the past.

Because the whale shark is an endangered species, and if we are to encourage the return of the hundreds of whale sharks that used to frequent this region, it is a priority to carry out further scientific research to respond to the declining numbers and seek to minimize any threat. More will have to be done to promote conservation and protective actions to ensure that whale shark habitats are in optimum condition and that tourists and boat operators comply with the regulations governing whale shark tourism, particularly regarding boat numbers and the number of tourists permitted to swim with each whale shark at any one time.

With this knowledge, in 2023 we will initiate the second phase of this project focusing on continuing to monitor whale shark habitats and tourism while also focusing on investigating their feeding habits in areas where they accumulate. Previous studies have already verified the close relationship between the abundance of the whale shark in the area and the availability of its food (zooplankton). In phase 2, we will explore these types of variables in detail, seeking to answer questions regarding the spatial and temporal variations observed in the abundance of sharks in the area.

Disseminating technical and scientific information about whale sharks

To commemorate the International Whale Shark Day celebrated on 30 August 2022, and as part of the activities of the 7th Whale Shark Festival, SAC-TUN supported the display of a photographic exhibition, entitled The Giant of the Seas, in Holbox central park to share information about the species and highlight the importance of carrying out responsible tourism activities to minimize negative impacts. On August, we were invited by the Mexican Association of Veterinary Doctors Specialized in Zoo, Exotic and Wild Animals (AMMVEZOO) to give a virtual talk on our research into whale sharks to a group of 50 students and professionals from the veterinary sector.
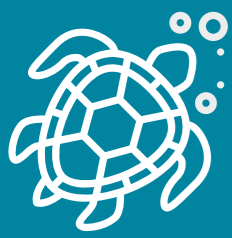
CONSERVATION OF CRITICAL MARINE TURTLE NESTING HABITATS, CONNECTIVITY AND POPULATION PARAMETERS IN THE NORTHEAST OF THE YUCATAN PENINSULA, 2019-2022

In the first three-year phase of this project, SAC-TUN and four other partners supported Pronatura Yucatan Peninsula in:

•**Registering and protecting 27,384 turtle nests** (7,302 hawksbill, 19,999 green and 3 leatherback turtles). Ninety percent of these nests were located on the coastal dunes of El Cuyo and Holbox beaches, suggesting that protecting, restoring and conserving these coastal dune ecosystems will be essential for the conservation of marine turtles in the northeast Yucatan Peninsula.

•**Releasing 2,025,592 marine turtle hatchlings to the ocean** (612,390 hawksbill, 1,408,920 green and 283 leatherbacks of which an estimated 250,147 hawksbill, 1,408,920 green and 282 leatherback hatchlings were released in 2022).

Monitoring and protection of clutches in the next phase of the project will continue to be fundamental to maintaining a high production of hatchlings and increasing the size of marine turtle populations in the region.

•**Monitoring and protection of 25 km of El Cuyo and 34 km of Holbox beaches over 458 days.** These are the principal beaches where marine turtles lay their eggs, and both are considered among the 14 most important for hawksbill and green turtle nesting in the Atlantic Ocean. As index beaches, they are used as thermometers of some of their reproductive parameters and the recovery of the populations of these species.

Our monitoring during the study period overall, and analysis of the nesting trend in the last 30 years, showed that the number of eggs laid by both green and hawksbill turtles increased on both El Cuyo and Holbox beaches, as well as on other studied beaches in the Gulf of Mexico – making this one of the few regions in the Wider Caribbean where populations of marine turtles show an increasing trend.

Density of clutches in El Cuyo

On El Cuyo beach, we observed an increase in the density of hawksbill nests per kilometre from 2019 to 2022 (except 2020). In 2019 and 2021, the highest nest density was observed on the east beach (more than 60%), while in 2020 it was concentrated on the west beach. The change in the spatial pattern in 2020 was probably due to increased rainfall that year which influenced a more homogeneous distribution between the beaches. We were also unable to make a complete record of clutches deposited in 2020 due to the pandemic.

In 2022, the density was similar on both beaches, with 56.6% registered on the east beach and 43.4% on the west; this could be due to the 78% increase in the number of registered clutches.

We observed no changes in the patterns of spatial distribution in the density of green turtle clutches in El Cuyo, with more than 90% of the registered clutches concentrated in the west beach over all four seasons. However, we observed changes between seasons: in 2020 and 2022, the number of nests per km (267 and 176 respectively) was higher than in 2019 and 2021 (130 and 126 nests/km respectively). This is consistent with the biannual pattern for this species.

The results from 2022 confirm that both segments of the beach are important for both species of marine turtles and that actions are necessary to minimize the threats that affect these habitats. Two of the main threats are the erosion of the west beach, which is the preferred nesting site for the green turtle, and the unplanned tourism development that is occurring rapidly on the east side where the hawksbill turtles prefer to lay.

Density of clutches in Holbox

In Holbox, the patterns of spatial distribution of hawksbill clutch density were similar during the four seasons between 2019-2022, presenting a homogeneous distribution along the 24 km of beach. However, we observed a yearly change in the number of nests per kilometre: in 2019 the density was 43.53 nests/km, in 2020 it dropped to 31.88[6], then increased to 58.71 in 2021 and decreased slightly to 57.46/km in 2022. The overall increase in clutch density is a positive sign of the population growth of this species.

Green turtles maintained their concentration of clutches in the first 17 kilometres at the western end of Holbox beach over all four seasons. However, nesting density decreased each year from 32 nests/km in 2019 to 21 nests/km in 2022, breaking the pattern of a season of high density followed by one of low in 2021. It is not clear what caused this apparent decrease: it may be that the females preferred to nest on other beaches such as El Cuyo and Las Coloradas because they did not find adequate conditions in Holbox, or it may be that results were skewed by our transport problems which led to fewer clutches being counted. Monitoring nesting in the following seasons will be essential to clarify these unknowns.

Distribution of clutches in the beach profile in 2022 was similar to the three previous seasons, with a marked preference for the dune area.

Development of a marine turtle database

In the first three years of this project, we supported the ongoing development of a marine turtle database for which we collated, synthesised and homogenised historical information from the past 30 years concerning marine turtle behaviour on El Cuyo, Holbox and five other beaches in the Gulf of Mexico.

Analysis of these data showed that the overall trend is towards an increase in both hawksbill and green turtle nests. However, growth was not uniform, with hawksbill nests increasing between 1990 to 1997, then decreasing until 2005, increasing rapidly from 2006 to 2014 and remaining relatively stable since. Green turtles, on the other hand, significantly increased from 1990 to 2021 but presented a biannual pattern characterized by a peak in even years and a decline in odd years from 1990 to 2004, then reversed this pattern from 2005 to 2009 with a decline in even years and an increase in odd years. Then the number of green turtle clutches decreased in Holbox and increased in El Cuyo until 2020, followed by a decrease in the number of nests on

both beaches in 2021. In 2022, in El Cuyo, hawksbill nesting increased by 78.12% and green turtle nesting increased by 39.53%. However, in Holbox, the number of clutches of both species decreased by 2%.

Between 2019 and 2022, the mean annual growth rate of hawksbill turtle clutches increased at both beaches from 7.15% to 9.63% in El Cuyo and 7.48% to 7.71% in Holbox. However, in green turtles, the rate decreased from 14.34% to 13.97% in El Cuyo, and from 14.86% to 11.90% in Holbox.

The spatial pattern of clutch density did not change over the three-year study period but there was a general increase in the number of nests per kilometre, except for the green turtle on Holbox beach. An analysis of these data entitled "Trends in reproductive indicators of green and hawksbill marine turtles over a 30-year monitoring period in the southern Gulf of Mexico and their conservation implications" was published in the scientific journal *Animals*[7], discussing this variation in reproductive indicators of hawksbill and green turtles over the last 30 years.

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[6] *The apparent reduction in nest density in 2020 may have been caused by our inability to fully register all clutches dues to the pandemic.*

[7] *https://www.mdpi.com/2076-2615/12/23/3280*

Marking and recapture of females

We have two objectives in marking and recapturing female marine turtles: to know the connectivity of the nesting and feeding beaches of each species; and to know the proportion of neophyte females (first marked) and expert females (previously marked). Between April and October 2022, we tagged 150 neophyte females, making a total of 546 females tagged from 2019–2022. We also identified fifteen females tagged in previous seasons.

Fewer turtles were tagged on Holbox due to our inability to monitor the beaches in the second third of the season because of transportation problems. Consequently, the proportion of green turtle neophytes and experts could not be estimated.

As in previous seasons, in 2022, at both beaches, the proportion of neophyte females was higher than that of experts. In El Cuyo, the proportion of hawksbill neophytes to experts was 8:1 and that of green turtles was 30:1. In Holbox, the proportion in hawksbill turtles was 4:1. Compared with numbers from earlier seasons, this indicates that the breeding populations of both species continue to increase.

Recapture of female hawksbill turtles demonstrates their strong fidelity to their nesting sites. In 2022, 71.42% of the hawksbill females recaptured in El Cuyo and 87.5% in Holbox were tagged on those beaches. In green turtles, only 50% of the recaptured females had been tagged in El Cuyo. It was not possible to estimate this percentage in Holbox.

Among recaptured turtles, a hawksbill turtle was identified in El Cuyo that was tagged in 1998 (24 years ago) in Las Coloradas, was observed that same year in El Cuyo, then was observed in 2001 and now in 2022 in El Cuyo again. This is the sixth record of females (4 hawksbills and 2 green) that have been nesting in the northeast of the peninsula for more than 20 years and demonstrates the strong connectivity between the beaches of Las Coloradas, El Cuyo and Holbox.

Importance of Florida feeding grounds for turtles that are born and return to lay in Yucatan

For the first time, in 2002 we identified a hawksbill turtle on Holbox that was tagged in 2005 on the east coast of Florida, USA, as a juvenile. It was recaptured several times in its feeding area, and in 2010 it was recaptured to place a satellite transmitter to follow its movements. Although the transmitter had already stopped transmitting, it was still attached to its shell when we observed it in 2022 on Holbox beach. This is the first record of a hawksbill hatched in the northeastern Yucatan Peninsula, reared on the east coast of Florida, and returned to nest on its birth beach 17 years after being tagged. This finding, in addition to identifying one of the feeding habitats of hawksbill turtles that nest in the Yucatan peninsula, opens the doors to future collaborations to establish comprehensive conservation measures between Mexico and the USA.

Disseminating knowledge of the importance of marine turtles

Through videos, talks, informative notes, social media posts, scientific articles, and recreational activities we have helped to educate more than 54,208 people about the importance of marine turtles and the threats to their survival from beach erosion, tourism development in sand-dune areas, and indiscriminate garbage disposal of plastics and other wastes.

Analysis of tissue samples

We collected 207 marine turtle tissue samples from 2019-2022 which have been catalogued and inventoried by the NOAA Southwest Fisheries Science Center and are now with the University of Georgia for analysis. Results of this analysis and the publication of an article will be completed later this year.

Lessons learned

Over the three-year monitoring period, storms, hurricanes and other bad weather events limited our nightly tours of nesting sites, with the ports of Holbox and El Cuyo closed on several occasions. For this reason, we switched to daytime monitoring visits to count the clutches.

COMMUNITY MANAGEMENT AND CONSERVATION OF THE AQUIFER AND CENOTES IN MAYA KA'AN AND THE RIVIERA MAYA, QUINTANA ROO, 2019-2022

SAC TUN has been supporting Amigos de Sian Ka'an to promote Maya Ka'an as a sustainable tourism destination based on sustainable communities. One of the main focuses in the first three-year phase of this project was to strengthen water governance and improve water management by introducing water committees in 22 communities of the Maya Ka'an to guarantee the permanence of water actions, and to construct eco-technologies to assist with conservation and sustainable use of water resources. To further consolidate in the populations a socio-environmental vision of natural resources we also introduced environmental education and citizen monitoring of water quality.

The first phase of this project aimed to achieve five goals by 2022, namely to:

1. Develop a Community Water Governance Strategy (EFGHC for its Spanish acronym) in 22 communities of Maya Ka'an.

2. Train teachers and students from at least 12 schools in Maya Ka'an and Playa del Carmen through the campaign You are Water, Be Aware! and our Guide to good practices for the conservation and use of cenotes and their caves.

3. Strengthen the participation of teachers and students from at least 12 schools in Maya Ka'an and Playa del Carmen in the use and care of aquifers and cenotes by generating information about the quality of water in their communities.

4. Strengthen the capacities of owners and users of 9 properties with cenotes for the adoption of good practices for their use and conservation.

5. Improve the capacities of operators of Wastewater Treatment Plants (PTAR) of 12 hotels in the Riviera Maya.

Developing a Community Water Governance Strategy in 22 communities of Maya Ka'an

With the support of SAC-TUN, by the end of 2022 Amigos de Sian Ka'an had successfully initiated their Community Water Governance Strategy in all 22 participating communities in the municipalities of Felipe Carrillo Puerto and José María Morelos in the Maya Ka'an region. Key advances in 2021-2022 include:

•Carrying out socio-environmental diagnoses in 14 communities to define which eco-technologies would be built, impact indicators of the project and methods for Friends of Sian Ka'an to offer supportive follow-up and strengthen the community organizations.

•Detailed presentation of the Community Water Governance Strategy in 22 communities in which the communities learned about and discussed with Friends of Sian Ka'an the catalogue of eco-technologies, their operation, benefits and relevance in terms of the socio-environmental diagnosis. Altogether, 1,143 people from 22 communities participated in our different workshops, community events, meetings, assemblies, festivals, environmental education actions and citizen science activities.

•Formation of water committees in 7 communities (San Antonio Segundo, Tzukum, Dzaptún, Yaxche Chal, Sahcabchén, Santo Domingo) which led to the construction of 86 eco-technologies for water (6 rainwater catching roofs, 40 rainwater capture systems, and 40 cisterns), and their maintenance.

•Supportive follow-up visits to the 6 communities where the ecotechnologies were installed to identify and resolve any problems in their installation and construction.

•Open training through our Water and Life Festival for 542 adults as well as minors in the 22 communities on the geological-hydrological conditions of the territory they inhabit. The aim was to strengthen participants' sense of community, interest in conservation, and their ownership and appropriation of ecotechnologies for their proper water management.

•In all, our Community Water Governance Strategy, installation of ecotechnologies and information outreach will benefit 3,467 people (48.8% women, 51.1% men) from indigenous communities.

Training teachers and students in good practices for freshwater management and conservation

This is part of our efforts to encourage the use of scientific information to reinforce decision-making by local stakeholders, which is essential for water management, governance and conservation.

It was a little problematic getting started again with our educational programs in the aftermath of almost two years of pandemic shutdowns, following which many hard-to-access schools presented difficulties in resuming their regular activities. By May 2022, we had restarted our Environmental Education Program entitled You Are Water, Be Aware! which includes components on good practices in cenotes and waste management. With the inclusion of 6 new Maya Ka'an schools in 2022, by the end of the first phase of project we had reached 571 students (53% women and 47% men) and 17 teachers (60% women and 40% men) from 10 schools in 9 communities.

Citizen science program with student participation in the monitoring of water quality in aquifers and cenotes

From the beginning of the project to date, 102 students (62% women and 38% men) who have completed the You are Water, Be Aware! educational program are now participating in our Citizen Science program and are monitoring a total of 24 freshwater sites (6 cenotes, 6 wells, 1 river, and 11 cisterns). This includes 12 schools[8], nine of which began participating in our Citizen Science program in 2022. Seven of these schools are located in, and 269 students (46%) and belong to, a Mayan community.

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[8] Includes 3 schools which actively continue with their community water monitoring program and 9 new schools in which we began training for monitoring and measuring water quality in 2022.

From the data obtained so far, we have observed that there are no high degrees of faecal contamination in most of the sites, with only Doña Dolores Well located in Yaxley showing contaminated water, meaning it is unadvisable to ingest, have primary contact or water plants with this well water without prior treatment. However, all the sites of all the communities exceed the recommended maximum levels for drinking water in nitrites (0.05 mg/l) and Nitrates (5 mg/l), meaning it is NOT recommended to consume water from any of these wells and cisterns without prior purification, since these parameters may indicate contamination by wastewater, fertilizers and detergents.

In phase 2, we aim to encourage the involvement of more parents in these projects, both in terms of taking an interest in their children's capacities to generate scientific information and, in particular, in assisting with the field trips which are fundamental to our Citizen science program.

Strengthen the adoption of good practices for the use and conservation of cenotes

In all, we trained 25 sustainable companies in the comprehensive management of cenotes, caves and springs, including 13 members of four remote community tourism companies, Siijil Noh Ha, Community Tours Sian Ka'an, Balam Nah Kíichpam K'áax and Selva Bonita, all of which achieved their Certification in Protection and Sanitary Prevention in Tourist Facilities (CPPSIT) in 2022. It can be challenging for community tourism companies operating in remote areas without adequate internet and other communications access, to comply with institutional guidelines. Close and continual follow-up is required if they are not to become frustrated and loose motivation to continue following the recommendations.

Recognising the importance of continuing to offer opportunities for off-grid communities to be kept in the loop and made aware of conservation and environmental initiatives, we collaborated with the National Institute of Anthropology and History (INAH) to design and produce a comic that promotes the care and protection of the cenotes while facilitating understanding by both local residents and tourists of the natural, historical and cultural values of the state of Quintana Roo. The comic is entitled Labyrinths of Water and will be published in 2023.

Improve the capacities of Wastewater Treatment Plants operators

From October 2022-February 2023 we will held our third training course leading to the Diploma in proper management of wastewater treatment plants as a tool to improve the health of the Mesoamerican Reef, and towards the application of NOM-001-SEMARNAT-2021. The purpose of this diploma course is to promote the adoption of good practices in the tourism sector, through the professionalization of treatment plant operators and operating personnel and decision-makers involved in water management in the Riviera Maya. Thirty-nine participants from 22 institutions completed this diploma: 2 from the academic sector, 1 from the social sector, 8 from the private sector, 5 from the public sector and 6 from the hotel sector.

Lessons learned

In achieving these goals and fulfilling the objectives of this project, Amigos de Sian Ka'an has encouraged active appropriation and community ownership of both freshwater resources and ecotechnologies, and developed solid relationships of trust with participating communities that will allow us greater efficiency as we move into phase II.

In implementing our Community Water Governance Strategy, Amigos de Sian Ka'an personnel have learned to adapt to the individual conditions and needs of each community in assisting them on their journey towards resilience and self-management governance processes. To further generate meaningful and fruitful relationships in the future, we will continue and strengthen collaboration and work with an intercultural approach, respecting and acknowledging the cultural differences between the various participants. We will also strengthen our team's linguistic skills to make better use of the Mayan language, which will improve information exchange and simultaneously foster better inclusion of the region's cultural heritage.

SUSTAINABLE FISHERIES THROUGH COMMUNITY PARTICIPATION IN THE MESOAMERICAN REEF SYSTEM, 2019-2022

This project aims to demonstrate that when small-scale fishers (men and women) take sustainability into account in their fishing activities and work together to share their available resources, everyone wins - their families and the social structure of their communities in terms of generating more regular and secure income, consolidating mutual trust and improving communication.

The principal goals were, by 2022:

•For citizen scientists[9] to be monitoring 16 fish refuges and 10 commercial fishing areas to get a clearer understanding of the ecology of fish spawning sites, particularly for grouper (*Epinephelus striatus*), and the size of their populations, as well as the movements of lobsters from fish refuges into commercial fishing areas.

•To generate information from two of the most important fisheries in the Mexican Caribbean, Sian Ka'an and Banco Chinchorro, on the socio-ecological connectivity of their communities and shared fishing resources to improve their management.

•For fishers to have co-designed adaptation strategies to global shocks and changes to keep their fishing sustainable, and to have shared their solutions with other fishers elsewhere in the Mexican Caribbean and the world.

Citizen science for monitoring fish refuges and spawning sites

By the end of 2022, we were carrying out biophysical and acoustical monitoring within 12 fishing refuges and three commercial fishing zones, with the support of 29 citizen scientists (seven women and 22 men) from three fishing cooperatives, and CONANP personnel.

The biophysical monitoring involved sending teams of divers to install oceanographic sensors to measure sea temperature and level, deploy band transects to estimate sizes and abundance of spawning aggregations of fish, specifically groupers, and to collect other data on fish of commercial and ecological interest, type of seabed substrate, corals and key invertebrates. They also installed passive acoustical monitoring sensors to record the sounds of various fish species as they gather in different spawning aggregation sites, which were later sent for analysis and interpretation. Other citizen scientists conducted lobster marking activities and collected water samples from different depths and tissue samples from different fish species, at various sites, which were sent for DNA analysis.

This environmental information seeks to demonstrate the connectivity between the different fish spawning sites across Quintana Roo, as well as generate alternative methods of estimating abundancies of fish and diversity of species present.

Underwater monitoring

Underwater monitoring activities were carried out with the support of 23 men and women from 6 fishing cooperatives from the communities of Banco Chinchorro, María Elena, Punta Allen and Canal Nizuc, in coordination with the Biosphere Reserves of Banco Chinchorro, Sian Ka'an and Sian Ka'an Reefs, and management from the national protected areas of Isla Mujeres West Coast, Punta Cancún and Punta Nizuc. Monitoring was usually carried out during the closed lobster season (March 1 to June 30).

Oceanographic sensors

Over the course of this project, we installed eight hobo-type loggers to record data on sea temperature[10] one to record data on sea level[11], and 3 acoustic sensors[12] to record the sounds at fish aggregation sites in five fishing refuges and four control sites outside the protected zones. One of the oceanographic sensors installed in Punta Herrero was withdrawn in 2019 but the others continue to operate effectively.

We collected 308,613 temperature and sea level records in the communities of Banco Chinchorro, Punta Herrero, María Elena and Punta Allen. Data from the two sensors installed in December 2021 in Xcalak and Punta Allen are still waiting to be recovered. Results to date show that temperatures oscillate between 20.9 °C and 31°C, averaging 28°C, with a maximum of up to 33.3°C. The coldest month for the Sian Ka'an site is January, while for Banco Chinchorro, it is March. The warmest month in Sian Ka'an is August-September, and in Banco Chinchorro, October. Sea levels averaged around 60 PSI, with a maximum of up to 70.8 PSI.

Band transects to monitor fish aggregations in spawning sites

In April 2022 in María Elena, eight people from two cooperatives monitored seven sites, four within the fishing refuge and three control sites. Their data from band transects reflect a considerable decrease in the number of fish registered between 2016-2021 and 2022, with only 18.5% of the annual average registered and no grouper recorded in the 2022 transects. The reason for the decrease in numbers is not clear.

Also in April 2022, in Canal Nizuc, five people (four men and one woman) participated in underwater monitoring activities during which 95% of the total fish observed in band transects measured 0-20 cm, with the largest number of these (2,172) measuring 0-5 cm. The channels and mangrove habitat in this area are important refuge zones for larvae and juveniles.

We monitored the Banco Chinchorro fishery for the first time in September 2022 when we arranged a field trip there, during which 23 people (5 women) were trained to join the community monitoring

group. Monitoring activities there were not possible before this due to the COVID pandemic. Divers visited five sites, two in the fishing refuge, two control sites and one site assigned by ANP management during which snappers (*Lutjanidae family*) were the most abundant fish species, followed by chac-chíes horse mackerel (*Trachurus trachurus*) and groupers.

Water, tissue and environmental DNA sampling

From 2020-2022, 87 fishers (men and women), with the assistance of 21 researchers, and CONANP staff, were actively working as citizen scientists collecting data from 12 marine reserves.

In all, we collected 66 water samples for analysis, 54 from Punta Allen and 12 from Xcalak - 9 from El Blanquizal (verified as a multi-specific spawning site for grouper species), and 3 from control sites. We also collected a total of 110 samples of environmental DNA and tissue from three spawning aggregation sites of fish of commercial interest, two in Punta Allen and one in Xcalak, and at two control sites in each location.

During the final year, with the aim of enriching the fish genetic information database for different aggregation sites, we chose to include other species besides *E. striatus* in our collection of tissue samples to be sent for analysis. For this reason, we invited more people from the Cozumel and Pescadores de Vigía Chico cooperatives to work together with us, specifically seeking out people of different profiles who contribute value to the fishing network, such as fishing technicians, marketing managers in the cooperatives, and restaurant owners in the communities.

In 2022, we trained seven of these new people to join our tissue collection teams to make a total of 21 people (38% women) who took fish samples for the most part from fish caught during the fishers' usual workdays. At Punta Allen, 37 fish tissue samples were collected, of which 22 were Caribbean grouper and the rest from six other species. In María Elena, seven samples were collected, four of Caribbean grouper and the rest of black grouper (*Mycteroperca bonaci*) and anchovy (*Lachnolaimos maximus*) which were observed in a multispecies aggregation. Fishing is ca-

rried out on a smaller scale in María Elena which is why just 16% of samples were made here compared to the 84% of samples collected in Punta Allen.

We forwarded the collected samples to the University of Arizona for genetic analysis using a PCR test designed in 2020 for detecting E. striatus DNA. The first samples taken from Punto Allen suggested the overall good reliability of this test for detecting *E. striatus* individuals present in spawning aggregations. However, the PCR tests on samples collected in January 2022 in Xcalak and María Elena raised some questions because they did not amplify *E. striatus* DNA, and slightly amplified two samples from phylogenetically close species, suggesting that the test may not yet be species specific, or that there is significant genetic variation between *E. striatus* individuals from different locations, which has not been previously reported, or that the environmental DNA amplification levels for *E. striatus* in locations other than Punta Allen are so low that it is not possible to detect them with the naked eye in a gel. For more accurate results, we will have to use a mitochondrial gene test (more sensitive, but expensive) or need to collect more samples and from other locations so that we can refine the accuracy of the PCR test. Community partners will continue to collect samples during the 2023 spawning season to ensure continuity of the study.

Acoustical monitoring

Simultaneous passive acoustic monitoring in Quintana Roo spawning aggregation sites is contributing to better understanding the temporal dynamics of fish movements in each site, as well as the similarities between them.

With the collaboration of local citizen scientists, researchers, and CONANP personnel (seven women and fifteen men), between December 2021 and June 2022 we installed temporary anchoring systems and connected hydrophones at three of the most important reproductive aggregation sites of three grouper species for passive acoustic monitoring. During the 2022 spawning season, we collected the recorded systematic and simultaneous audio data, first from the sensor in Niche Habin, Punta Allen, and subsequently from the sensors installed at San Juan (Punta Allen) and El Blanquizal (Xcalak).

In all, over the course of this project we collected 1,068 hours of audio data of different species recorded at the three sites. The instruments reflected a greater acoustic activity between 9-12 days after the full moon, with activity peaks at sunrise and sunset for *E. striatus*. When taking data in several locations simultaneously, we observed a slight delay in spawning days (+ 9-10 days after the full moon in Punta Allen, + 12 days in Xcalak). However, these results change for other species, such as poisonous *Mycteroperca,* which peak in numbers on the seventh day after the full moon and demonstrate maximum activity in the afternoon (3-6 pm).

Our results revealed the similarities and differences in the vocalizations of four species of groupers. As a result, we adjusted the algorithm used for the acoustic data (FADAR program) with our data from the Mexican Caribbean, since the groupers from our region show a higher (shorter wavelength) vocalization tone than the one registered in other regions of the Caribbean. This is the first time this data has been recorded and its inclusion in the algorithm will make it possible to improve grouper detection systems and contribute to better understanding the dynamics over time of grouper aggregations both in the three sites we monitored and across the entire region.

In the process of conducting this research, two women and a man from the Punta Allen community monitoring group instructed a group of researchers from the Center for Technological Studies of Chetumal and people from the administration of the ANP of Xcalak, demonstrating the scaling-up potential of our project, and its contribution to strengthening technical knowledge and providing continuity to passive acoustic monitoring in Xcalak.

Community partners were invited to speak for themselves in assembly meetings to present their findings to other members and from other communities. The collective results of all the analysed monitoring data were presented to the cooperatives in workshops, along with other results of this project. Results revealed a decreasing abundance of all the fish (62-73% less) over the study period for all the monitored sites (Sian Ka'an and Banco Chinchorro).

Lobster marking

The data collected in this study allows us to evaluate and compare the structure of lobster populations in two communities of the Sian Ka'an Biosphere Reserve, Punta Allen and María Elena, and contribute to evidencing the influence of this fishing refuge on lobster population structure (sizes and sex ratio).

With the support of 17 people (13 men and four women) from two fishing cooperatives, we tagged a total of 726 Caribbean spiny lobsters (*Panulirus argus*): 156 lobsters in María Elena with six recorded recaptures, and 570 in Punta Allen with 27 recorded recaptures. In both locations we caught most lobsters on rocky bottoms and caught more females than males, although in Punta Allen the ratio of differences between the sexes was just 3.2% compared with a 14.2% difference in María Elena. In both communities the number of lobster juveniles was low (María Elena: 0%, Punta Allen: < 6%). In María Elena, the vast majority were classified as adults, while in Punta Allen the vast majority were classified as subadults (reported previously in the literature). The difference in lobster size may be because most of the tagged lobsters in María Elena (92.3%) were caught and released inside the fishing refuge, while in Punta Allen all the data come from commercial fishing grounds.

Five percent of the caught lobsters were recaptures, 60% of which moved less than 1 km away from where they were caught, and 6% of which moved more than 12 km away. In both fishing cooperatives, all 180 partners and workers were aware of the need to report recaptures. The recapture data documented the overflow effect of tagged lobsters moving from the fishing refuges towards four lobster fields in the commercial fishing areas where they were recaptured and sold since they met the commercial size, highlighting the importance of fishing refuges as a tool for management of resources.
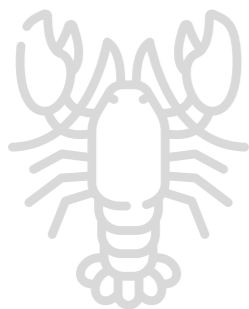
Socio-ecological connectivity

In the course of the project, we investigated the social networks of six different fishing cooperatives in Sian Ka'an and Banco Chinchorro to find out more about their socio-ecological links. We studied how individuals interact, how their fishing systems are organized and collected data on the social and commercial relations between the different members. We interviewed individuals to find out which actors they consider important to their fisheries, either for their help with work, or for taking actions that allow them to work, or who influence their decisions, or with whom they do business.

Social connectivity in Sian Ka'an

The three Sian Ka'an cooperatives evolved from a single cooperative in Cozumel and share the same small-scale fish resources where their principal catch is spiny lobster (*P. argus*). However, there are no formal institutional arrangements for collaboration between them although they collaborate with other actors to promote the sustainable management of fisheries. Some government institutions are not present in the territory and their absence, especially in fisheries matters, has left a void that has been filled by the cooperatives, civil society organisations, and academia. This, in the long term, has strengthened the cooperatives' internal organization systems and fostered collaboration between non-community actors. Interviews conducted in 2020 during the COVID-19 pandemic showed that the cooperatives identify themselves as the principal players responsible for leading key management actions. The fishing cooperatives likewise recognize themselves and civil society organisations as the principal players responsible for leading citizen science efforts to generate objective, verifiable, and standardized scientific information for decision-making focused on achieving sustainability of fishing activities. There is frequent communication and a high level of trust between the fishing communities and COBI.

Social connectivity at Banco Chinchorro

In 2022, we conducted a social connectivity study in the Banco Chinchorro Biosphere Reserve which replicated the 2020 study carried out in Sian Ka'an. We conducted 56 interviews with members of the three fishing cooperatives that operate in Banco Chinchorro (Andrés Quintana Roo, Langosteros del Caribe and Fishermen from Banco Chinchorro). The study revealed the close kinship relationships between the three cooperatives of this biosphere reserve, as well as occasionally with the José María Azcorra cooperative, in Punta Herrero, Sian Ka'an. It highlighted the low mobility of people dedicated to fishing, most of whom come from Chetumal or nearby communities, little migration of cooperative members and very few immigrants from other states of the Republic. It also highlighted the role of family (own or partner's) in the transmission of knowledge related to fishing. Interviews also showed that the three cooperatives collaborate on issues of fisheries management, as well as with other actors outside their community (CONANP, SEMAR and COBI, mainly). Most people trust other actors outside the community although 14% of the people surveyed mentioned little or very little trust in public institutions (CONANP, PROFEPA, SEMAR, INAPESCA and SEMARNAT). The frequency of communication with external actors changed from very frequent before COVID-19, to frequent or regular during the pandemic.

Exchange of citizen science experiences

Throughout the project, we organised a series of both face to face and virtual meetings where men and women from the coastal communities could meet to collaborate and discuss such topics as citizen science, biological and environmental monitoring, installation and use of oceanographic and passive acoustic sensors, gender equality, *PescaData* management, and other themes. These meeting were opportunities for participants to discuss their own experiences and to learn from others. We also organised training workshops where our citizen scientists instructed other people (among them researchers) in the replication of successful monitoring actions. For example:

•In July 2022, we held a workshop in Ensenada (Baja California) with members of a federation of fishing cooperatives, and researchers from Stanford University and the University of Georgia (United States) which included an exchange where a member of Punta Allen presented their experiences in citizen science for connectivity genetics.

•In September 2022, we held talks in the communities of María Elena, Punta Allen, Banco Chinchorro and the island of Cozumel in which seven men and five women spoke both to their own and to outside communities of their experiences as citizen scientists.

•In October 2022, two members from Cozumel and Punta Allen participated in citizen science trainings with SAC-TUN staff.

Members of the Network of Fishermen and Fisherwomen[14] (one partner and two partners from María Elena, and one partner from Punta Allen) led activities in their communities to disseminate the benefits of belonging to this network and generate citizen science for the well-being of their communities. In this way, the network has been a tool to exchange solutions, share experiences, mobilize knowledge and generate citizen science. The people that make up these groups also participated in updating the Oceanographic, Passive Acoustic and Environmental DNA Monitoring Manual[15], which includes some community solutions that were included on PescaData[16].

These types of interactions strengthen autonomy and promote shared responsibility – both of which are key for the effective transfer of leadership.

[14] The Network of Fishermen and Fisherwomen is a space for collective action made up of people dedicated to fishing who work for the health of the oceans and for the sustainable use of sea resources. The network operates through thematic groups that have the objective of (1) generating citizen science, (2) transmitting knowledge between communities and fishing organizations, (3) generating alliances, (4) seeking the intergenerational well-being of communities, and (5) mobilizing knowledge, solutions and capital.

[15] https://cobi.org.mx/wp-content/uploads/2022/11/COBI-Manual-monitoreo-oceanogra%CC%81fico_23nov22.pdf

[16] PescaData is a mobile application aimed at connecting small-scale fishers to existing platforms to help them incorporate their catches into external traceability schemes while improving their technological prowess and administrative capacity and promote interoperability.

Design, curation and publication of solutions to problems confronting fishers in Quintana Roo

The aim of documenting community solutions for adaptation to change by the fisheries sector is for this to work as a catalyst for achieving common goals.

Due to the COVID-19 pandemic, the documentation of fishers' solutions to resolve the problems they confront had to be conducted online. This represented a challenge because some communities do not have internet services (one of the edges of the digital divide) or they felt uncomfortable at not having an in-person, one-on-one interaction. However, at the end of the virtual workshops, we had generated a space for dialogue rich in the exchange of ideas and experiences and the participants felt inspired to share more solutions. One challenge we still face, however, is the absence of a standard to assess what can be considered a community solution. We have begun to create a standard that could serve as a guide for these purposes, which will be finished in 2023.

By August 2022, we had documented 65 community solutions, 16 of them in Quintana Roo generated by seven of our cooperative partners. Three of these solutions appear on the *PescaData* cell-phone application[17] and 13 others are solutions implemented by COBI in collaboration with community partners which appear on the *Panorama Solutions* global platform[18]. Six of these were published in 2019, four or which include contributions from fishermen and women from the Caribbean (marine reserves, citizen science, technological innovation, recovery of ecosystems through collective action). Each solution contains four or five components that describe in detail the actions taken: three examples include: the role of citizen science in fisheries sustainability[19]; community monitoring of climate change; and NaturaLista: citizen observations of biodiversity.

Other examples of documented solutions include consolidation of market options, management of invasive species, restoration of ecosystems, monitoring biological, genetic and acoustic parameters, unity and commitment in a cooperative, tourist cooperatives formed by women, modifications in fishing gear and waste management.

In October 2022, COBI offered technical support to encourage cooperatives to upload two more solutions on the Panorama platform: the first concerning invasive lionfish, and the second concerning the sustainability of the Caribbean spiny lobster fishery. However, the willingness of cooperatives to collaborate (especially online) is related to lobster market conditions and, if the price drops and causes concerns, they are less willing to participate in online collaborations. We are working to resolve this by taking advantage of fieldwork and are hopeful that the documented solutions will be available by the end of 2023.

We are also collaborating with a University of Miami PhD student who is currently conducting a year of ethnographic research among artisanal fishermen in Cancun to answer the question: How does the urban environment shape the opportunities and challenges for the resilience of livelihoods within small-scale fishing communities? This student is interviewing and observing fishermen from the SCPP Pescadores de Puerto Juárez (Cancún), a cooperative that has shown resilience in an urban environment by overcoming several major challenges (hurricanes, recessions, COVID-19 pandemic, etc) throughout its 35 years of existence in the heart of Cancun, as well as the perspectives of fishermen from a now-defunct neighbouring cooperative. The aim is to use this information to provide policy makers and academia with a clearer perspective of the most influential factors contributing to and threatening the livelihood resilience of fishing communities in urban settings. An article discussing this research was published in *https://ecologyandsociety.org/vol27/iss3/art46/*.

Other articles that have been published include:

•The voice of Mexican small-scale fishers in times of COVID-19: impacts, responses, and digital divide:
https://www.sciencedirect.com/science/article/pii/S0308597X21002177

•Between uncertainty and hope: Young leaders as agents of change in sustainable small scale fisheries:
https://link.springer.com/article/10.1007/s13280-021-01639-2

•Fisheries voices in the COVID-19 pandemic: small-scale fisheries challenges and solutions
https://cobi.org.mx/wp-content/uploads/2022/03/6.-COBI_The-Voices- of-the-coast-in-the-COVID19-pandemic.pdf

Renewal of Fishing Refuge Zones

Our continuous monitoring over the course of this project made it possible to generate information to support the fishing cooperatives in their requests to The National Commission for Regulatory Improvement (CONAMER) for renewal of 10 fishing refuges (two in Punta Allen, eight in María Elena). Their renewals were decreed between November to December 2022 and extend the protection of these zones for another five years, giving continuity to the conservation of fishing resources and validating the relevance of citizen science in the generation of public policy documents.

In conclusion...

At the close of the first phase of this project, by sharing responsibilities and leadership to implement monitoring actions, COBI has been able to expand its capacity for action in the field, without needing to be present at all spawning sites.

This project demonstrated that applying innovative methodologies such as environmental DNA and passive acoustic monitoring to characterize fish spawning aggregation sites are actions that can be largely directed by local collaborators, contributing to the generation of citizen science and collaborative alliances between researchers, national park administrators and users of fishing resources.

Delays in field activities caused by the COVID-19 pandemic led to the implementation of different forms of work, including remote work, which highlighted the adaptive capacity of people living in coastal communities to global changes. In some ways, the pandemic was a catalyst for members of the monitoring groups to play a greater role in the leadership of activities in the field. However, it was also challenging in terms of finding ways to communicate and return results back to the communities generating the information. It is important that citizen scientists can access and see the results of their participatory work, so that they can make use of the information they helped to generate and to feel valued for their contribution in making the science possible.

[17] *https://pescadata.org/*

[18] *https://panorama.solutions/en/solution/*

[19] *https://panorama.solutions/en/solution/ciencia-ciudadana-en-pro-de-la-sostenibilidad-pesquera*

Development of public policies in conservation areas of quintana roo, 2019-2022

Since 2019, SAC-TUN has been working with SEMA (https://qroo.gob.mx/sema), Amigos de Sian Ka'an, *(https://www.amigosdesiankaan.org/),* and the University of Quintana Roo *(https://www.uqroo.mx/)* to support the creation of three new parks and reserves, and to prepare the management plans of other, already-gazetted state protected natural areas.

The development of these projects was delayed somewhat due to the COVID-19 contingency, as were the public consultation periods, with some work having to be conducted online.

By the end of 2022, we had supported the research, preparation and development of technical studies, preliminary justification studies and decrees for the following three proposed new protected natural areas:

•Bacalar Lagoon National Park.
•Chemuyil-X'Cacel Forests and Wetlands State Ecological Park.
•Puerto Morelos State Ecological Park.

Between them, the creation of these three new ANPs will add 13,469 ha to the total expanse of protected natural areas in Quintana Roo (12,006 ha in the Bacalar lagoon National Park, 1,000 ha in the Chemuyil-X'Cacel Forests and Wetlands State Ecological Park, and 463 ha in the Puerto Morelos State Ecological Reserve).

Through SEMA, we have also supported IBANQROO, Amigos de Sian Ka'an and the University of Quintana Roo to research, prepare and develop comprehensive management plans and research studies for the following existing ANPs:

•Manatee Lagoon State Reserve.
•Chacmochuch Lagoon System State Reserve.
•Bacalar Lagoon State Ecological Park.

DECLARATIONS OF NEW PROTECTED NATURAL AREAS

Preliminary justification and social feasibility studies for the declaration of the Bacalar Lagoon National Park

The proposal is to reclassify the Bacalar Lagoon State Ecological Park into the Bacalar Lagoon National Park and include the Bacalar Lagoon and coastal wetlands within its boundaries, in this way adding an additional 12,000 hectares into the new expanded protected natural area.

Preliminary justification study for the proposed new Chemuyil-X'cacel Forests and Wetlands State Ecological Park

The proposal is to create this new ANP on 483 hectares of rainforests and wetlands bordering the sand dunes and the nesting beaches of the X'Cacel-X'Cacelito Marine Turtle Sanctuary. This operational framework presents an opportunity to guarantee and promote the conservation of representative and valuable transitional jungle and wetland ecosystems that play a pivotal role in the ecological health and dynamic processes that maintain and interconnect the coastal zones' reef, beaches, and dunes where marine turtles feed and lay their eggs.

Preliminary justification study for the creation of the Puerto Morelos State Ecological Park

The proposal is to protect 463 hectares of medium-sized forests and wetlands forming one of the last remaining continuous tracts of the ecosystem that originally extended from the south of Cancun to the south of Puerto Morelos. SAC-TUN supported, SEMA, IBANQROO and Amigos de Sian Ka'an in their online consultations with the State Council for the Management of Protected Natural Areas, and the preparation of the preliminary justification study for the creation of this new ANP which was published and made available for public consultation on the websites of both IBANQROO and SEMA. On conclusion of the period of public consultations and the corresponding incorporation of observations into the final draft, the finalised document was submitted for review by the State Government Legal Department together with a Decree proposal to legalise the park's creation.

Management plan and technical studies to strengthen the Manatee Lagoon State Reserve

The aim of this project was to protect and strengthen this reserve which was first gazetted in 1999 but had remained without a formalized management and administration plan. By 2022, we had succeeded in completing our four principal objectives, to:

1. Prepare a technical study and a draft management plan for the reserve.
2. Research the state of the habitat and population size of the different species of fish, crocodiles, manatees and other fauna inhabiting the lagoon.
3. Strengthen park administration, protection and conservation by training and equipping park rangers and educating local populations about the importance of the ANP.
4. Create infrastructure within the ANP to support management and administration activities and to provide healthy recreational spaces for visitors.

Draft management plan

Between 2019 and early 2020, we prepared a technical study of 234 hectares within the reserve, which describes the physical, biological and socioeconomic characteristics of the area, and includes an inventory of flora and fauna and their protective status, and information regarding land tenure, state patrimony and national assets.

The technical study showed that mixed mangroves protected under Mexico's NOM-059-SEMARNAT-2010 occupy 88% of the surface area, the Manatee Lagoon another 9%, with the remainder being intervened areas covered in invasive exotic species or without apparent vegetation.

The management plan proposes a core conservation area of 150 ha representing 64% of the entire surface of the reserve to protect the mangroves from the latent deterioration due to pressure exerted by the city.

Management plan for the Chacmochuch Lagoon System State Reserve

The 1,914.52-hectare Chacmochuch Lagoon System State Reserve is located north-east of Cancun and was officially declared on 16 August 2018

Twenty-three years after the creation of this protected natural area, we supported SEMA, IBANQROO and Amigos de Sian Ka'an in concluding their consultations and preparations for its management program which was presented to the Advisory Sub-Council of the protected area, validated, submitted to public consultation and is currently in the process of being legalised so that implementation can begin.

CONTACT

Sustainability
Karla González gonzalezk@vmcmail.com

 Facebook: SacTunMx

 Instagram: sac_tun_mx

https://sactun.com/

WEB SITE

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