APPENDIX

ACHIEVEMENTS IN THE SECOND YEAR OF THE 2019-2022 ENVIRONMENTAL STRATEGY

SAC·TUN

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

Since 2018, SAC-TUN has been supporting the Faculty of Natural Sciences from the Autonomous University of Querétaro to investigate jaguar movements and habitat across human-dominated landscapes in Quintana Roo.

Our objective in 2021 was to use both ground and satellite tracking techniques to continue monitoring for at least 12 months up to five jaguars as they moved throughout the Quintana Roo landscape, including on SAC-TUN properties. Both tracking methods have, in the past, provided good information about the movements of big cats and their prey.

Ground tracking

We used camera traps set up with scent and/or water baits and motion detector sensors to ground track the felines and automatically take photographs, day and night, whenever an animal passed in range.

In 2021, we bought 40 new cameras, 28 of which we placed on SAC-TUN's approximately 22 km^2 of land, 13 in La Adelita conservation zone between the gaps and trails established in 2018, 11 in La Cantera on the existing roads at the edge of the vegetation where vehicle traffic is limited, and four on El Corchalito close to the central offices near the port and sports area.

This provided us with 2,968 camera trap nights and 11,132 wildlife records belonging to 44 wildlife species.

More specifically, we obtained photographic records of three of the five felines placed with radio transmitters in 2020 (one male puma, one female puma and one female jaguar), in addition to obtaining information on their potential prey and smaller felines. These photographs complement the satellite tracking information from the felines' radio collar transmitters.

Combined results

We have been actively photo-trapping fauna this area since 2018, first from February to August 2018, the year in which the project began; then from October to December 2019; thirdly from January to May 2020 (a period that was interrupted by COVID-19) and most recently from February to June 2021 when we resumed photo-trapping after acquiring new cameras.

Between 2018 and 2021, camera-trap monitoring at SAC-TUN generated a list of 65 species of wildlife (four reptiles, 35 birds, and 26 mammals). When this is combined with the species recorded by direct observations, traces and footprints found during monitoring, a total of 91 species of wildlife are reported for SAC-TUN (10 reptiles, 52 birds and 29 mammals). Among the registered species, 26 are protected under various categories of Mexican Official Norm (NOM) 051.

Species that are difficult to detect such as jaguarundi *(Herpailurus jagouaroundi),* weasel (Mustela frenata), porcupine *(Sphiggurus mexicanus)* and grisón *(Galictis vitata)* have been successfully photo-captured by camera-trap monitoring.

The record of species considered conspicuous or less abundant throughout their distribution, such as the weasel, porcupine, grisón, jaguarundi and coyote *(Canis latrans)* represent important records in the area, since they can help enrich the ecological information available on these species at a regional level.

The grisón is one of the least known species of mustelids in America and its actual conservation status is unknown. The northern limit of its distribution is Mexico, where it is considered a threatened species although globally it is considered of minor concern by the International Union for the Conservation of Nature

Photos of species in 2021

Photographs taken in 2021 showed an increase in feline prey species such as coatis (*Nasura narica*), white-tailed deer (*Odocoileus virginianus*) and cereques (*Dasyprocta punctata*) as well as gray fox (*Urocyon cinereoargenteus*), opossums (*Didelphis virginiana*) and buzzard (*Cathartes aura*).

However, there was a decrease in photographs of puma (*Puma concolor*)[1] and feline prey species such as collared peccary (*Pecari tajacu*) and ocelot (*Leopardus pardalis*), as well as temazate (*Mazama pandora*), spider monkey (*Ateles geoffroyi*) and ocellated turkey (*Meleagris ocellata*) which are in different protection categories according to NOM-059.

Some species that were photographed in previous years, such as anteater (*Tamandua mexicana*) and armadillo (*Dasypus novemcinctus*), were not recorded in 2021.

Four species of reptiles were photographed: green iguana (*Iguana iguana*), gray iguana (*Ctenosaura similis*), basilisk (*Basiliscus vittatus*) and parakeet snake (*Leptophis mexicanus*).

Satellite monitoring

Satellite monitoring was carried out through radio transmitters that were placed around the necks of five captured felines in 2020 (two male pumas, one female puma and a male and female jaguar) before they were released back into the wild. These enabled us to log and follow remotely the paths of the animals as they roamed freely around the environment and, to date, we have obtained 1,766 locations of individual feline movements.

Between 20 January and 21 February 2021, we attempted to increase the number of felines with radio transmitter collars by setting up nine traps at different locations in the SAC-TUN properties, to catch and radio-tag them. None of these traps was successful so we are now waiting for the next (3rd) trapping period which is planned for January-March 2022.

Satellite tracking was continuous on all five felines from 2020 until different moments in 2021. Now, the only feline that continues to send constant information is the female jaguar. We have stopped receiving locations from the three pumas and it seems likely that their radio transmitter batteries have deteriorated. We received a mortality signal from the male jaguar in July 2021 indicating that he had not moved in more than 12 hours and was likely no longer alive.

Death of male jaguar

The male jaguar roamed the largest area (342 km^2) of all the radio-tagged felines. His radio transmitter showed that from February 2020 to March 2021 he remained south of Playa del Carmen, usually close to the Hacienda Yum-Balam reserve which rescues young and abused female and male jaguars, which may be what attracted him.

Signals after 12 March 2021 showed he was heading north of the Playa del Carmen-Tintal 305D highway through a developing area surrounded by small rural settlements with open vegetation and domestic animals such as pigs, chickens and calves.

By 4 June 2021, the male jaguar was located approximately one kilometer from the city's landfill, and he remained in this area until his death on 17 July 2021.

Ten days later, after obtaining the necessary permits, we went to investigate and to retrieve both the jaguar and his radio transmitter. An autopsy indicated that the male jaguar was probably around 11 years old when he died and, at some point in his past, had been wounded between the eyes and on the left side of his skull with shotgun pellets that were still embedded. He also presented damage to his jawbone, premolar teeth, and lower fang, all of which may have impacted his ability to hunt for food and eat, possibly leading to its death.

Movements of other felines

The satellite monitoring data showed that one of the male pumas roamed across 144 km^2 from Río Secreto to the Xpu-há lands. His last location was received on 24 June 2021 and his last photograph was taken on 22 June 2021 with a camera on the southern limit of SAC-TUN's La Adelita property.

The other male puma roamed an area of 241 km^2 south of SAC-TUN, including La Adelita, sending constant locations from his tagging on 10 February 2020 until 12 March 2021.

The female puma roamed a significantly smaller area of 31 km^2 covering the area north of Paamul and Río Secreto in coastal areas of Punta Venado. We received signals from locations from 14 February 2020 to 31 August 2020 (6 months of activity). A photograph taken from a camera trap in the center of La Adelita shows that this female puma was in good condition at least until 20 March 2021. She crossed federal highway 302 Chetumal-Cancún on 14 occasions between kilometers 277 and 280, possibly because of decreased vehicle movement due to the COVID-19 pandemic.[2]

Of the five felines captured, the female jaguar is the one that makes use of the smallest area (16 km^2). She moves through the sports and access booth of the port of SAC-TUN, between Punta Venado, the SAC-TUN offices, the Xcaret grounds, and the forest area south of Playacar. Her satellite transmitter has been continuously sending locations since her capture and release on 20 February 2020 until writing this report. She crossed federal highway 307 (Playa del Carmen-Tulum) on two occasions in September 2020, at kilometer 285, which may be related to decreased road traffic due to the COVID-19 contingency.

In October 2021, her transmitter issued a low voltage signal, indicating that the transmitter battery would run out shortly. However, based on the tracking information so far provided, we believe it will be viable to replace her transmitter.

We have a camera-trap photograph taken of this female jaguar with her two juvenile cubs on 30 August 2021. We believe the cubs were probably born in February 2021 when this jaguar registered comparatively fewer movements than in other months and, from her location, it seems that the cubs may have been born on SAC-TUN properties.

Camera trap monitoring

In 2020-2021, photographs from camera traps enabled us to identify 10 jaguar individuals by their distinct spot patterns, three of which had already been photographed in 2018. In total, we photographed eight females, three males and one juvenile of undistinguishable sex.

In all, between 2020 and 2021, we acquired 27,589 photographic records of wildlife, corresponding to 58 species: four reptiles, 25 birds and 29 mammals.

The camera-trap in El Corchalito twice gave us photographic evidence of the presence of a coyote. In the last 25 years, the range of coyotes has expanded markedly although its distribution in the state of Quintana Roo remains uncertain. It is thought that coyote expansion may be induced by deforestation which creates the open habitats coyotes prefer.

A note entitled *Recent Expansion of Coyotes in Quintana Roo State, Northeast Yucatán Peninsula, Mexico* was submitted in November 2021 and has been accepted for publication in the journal *BioInvasions Records*[3] This information contributes to the limited knowledge of the distribution of coyotes across the peninsula.

[1] Although the puma does not have a protection category, it is a large predator whose levels of abundance and density are considered important in terms of conservation.

[2] Based on this information, the scientific article entitled: "Female puma (Puma concolor) highway crossings in the Yucatan Peninsula" was published in 2020 in the Western North American Naturalist magazine 80 (4): 573-580. https://bioone.org/search?term=Female+puma+%28Puma+concolor%29+highway+crossings+in+the+Yucatan+Peninsula).

[3] Article in press. BioInvasions Records (2022) Volume 11. https://www.reabic.net/journals/bir/2022/Accepted/BIR_2022_Hidalgo-Mihart_etal_correcteproof.pdf

Evaluation of the level of use by felines of the quarry extraction area

Radio transmitter locations did not show any felines roaming within the quarry extraction area. However, we have photographic records of four feline species (pumas, jaguar, margay and ocelots) from most of the cameras placed on SAC-TUN's land in different locations of La Adelita conservation area, La Cantera extraction area, and near El Corchalito extraction area (not currently being used and in the process of recovery). Most photographs were from cameras placed in La Adelita.

We measured the distance from the cameras to the quarry area and found that most records for the big cats (pumas and jaguars) come from the cameras located more than one km from the quarry edge. There are also substantial pictures of all feline species taken by cameras located just 100 meters away, especially from those in the area behind the offices and outskirts of El Corchalito which, despite being modified, appears to be a passage zone both for felines and their prey.

The photographs demonstrate that, despite the SAC-TUN properties being an environment subjected to human use, the four species of felines frequently transit these areas. This could indicate that felines can tolerate a certain degree of change in their habitat. This tolerance could be influenced by many factors such as dietary breadth, behavioral plasticity, habitat requirements, and carnivore-human interactions. It is also likely that there is a pattern in the activity of these animals that is related to the hours of greatest activity of the company.

Determining the movement behaviour of felines

The activity and movement of big cats is influenced by the availability of resources, which generally changes depending on the season. We used the total number of locations for each of the five felines as indicative of their land communication routes and overlaid these on vegetation, rainfall and temperature maps to create home environment models, by year and by season, distinguishing between dry and rainy seasons.

We sought to obtain five approximations of the home environment for each individual: the first for the total period 2020-2021, then two for 2020 (dry and rainy seasons) and finally another two for 2021 (dry and rainy seasons).

Results indicated that, in general, the two male pumas and the male jaguar showed a greater range than the females of both species. In 2020, the average estimate of home range for the dry season was notably higher than the average for the wet season for the three pumas and the male jaguar. However, in 2020, the female jaguar ranged in a smaller area in the dry season.

Calculations for 2021 were not possible for either the female puma or one of the males since their radio transmitters failed to function.

We performed monthly analysis for the female jaguar based on the premise that the range for females is probably reduced in the month they give birth and that the month with the least range of movements in 2020-2021 was probably the birth-month of her two cubs which were photographed in August 2021. The least movements and smallest range were in February 2021, so we deduced that the cubs would have been around six months old when they were photographed.

It is probable that most of the identified jaguars use the SAC-TUN properties only as a transit area since there are no continuous records of the presence of most of them in the area throughout the monitoring period.

Habitat use

Vegetation cover can be relevant for the movement of big cats and their prey around an area fragmented by human activities. We determined the felines' habitat use based on the structure of the vegetation which, for most of the study area, is represented by secondary vegetation (*Selva mediana subperennifolia*) and to a lesser extent mangroves and some areas without vegetation.

A higher canopy tends to represent forest in better condition than a low canopy which, in our study area, represents areas fragmented by human activities, vegetation in the process of recovery, or coastal areas.

Genetic sequencing of species and number of individuals through analysis of fecal samples

Satellite data on the height of the canopy for the study area were represented by a layer in raster format from 2019 at a resolution of 30 meters using ArcMap 10 software.

We found the felines tend to range below canopies from 0-19 meters in height although canopies extend up to 22 meters in height.

Females were more associated with sites with lower canopies than the males. The female jaguar preferred areas where the canopy height is between nine and 12 meters, and she also frequented coastal areas dominated by shorter trees under canopies between three to 8 meters high.

In conclusion, the distribution of felines in the habitat was different from the available habitat. We plan to add other environmental variables that are available at higher resolution, if possible, to better explain this difference in usage. In addition, we will add seasonality to the distribution and apply a statistical test to find out if the differences found are significantly dissimilar.

Through genetic diversity, it is possible to analyse the evolutionary history of species, determine the genetic structure within and between populations, and infer the evolutionary potential of a population (Allendorf and Luikart, 2013). Currently, habitat fragmentation is one of the greatest threats to species in terms of genetic diversity, since the interruption of gene flow between populations affects their resilience (Fraser *et al*., 2019).

In 2021, we collected 25 feline fecal samples that were sent to the zoology laboratory of the Autonomous University of Querétaro for DNA extraction which was then identified, amplified and sequenced.

The results showed that 11 samples came from four jaguars (three males and one female), of which one male and one female are half siblings. Fourteen samples came from four pumas (three males and one female).

Dietary analysis for prey evaluation revealed a difference between jaguar and puma prey. In general, pumas feed on a broader spectrum of prey (cereque, pizote, tepezcuintle or lowland paca, peccary, and deer) while jaguars prefer pecari, pizote, tepezcuintle and armadillo.

Genetic analysis of fecal samples from two species of deer

Although there are numerous works that talk about the impact of fragmentation on genetic diversity in mammals, few have focussed on ungulate populations in the face of these changes (Fraser et al., 2019). In this project we aimed to determine the genetic diversity of two deer species, white tailed deer and Yucatan brown brocket (temazate) deer.

Genetic analysis showed that the 171 deer fecal samples collected between 2020 and 2021 belong to 18 individuals (six temazate and 12 white-tailed deer).

The genetic analysis for both species does not reflect, for the time being, inbreeding problems related to the fragmentation of the area. Although the estimated population for white-tailed deer (30 individuals) shows a small size, its genetic diversity presents higher values than those reported for isolated populations in other studies.

We expected the temazates' genetic diversity to be reduced as has been noted elsewhere in several species of the genus. However, despite its apparent isolation and being in an area impacted by human activities, the group in our area of study has a genetic diversity that suggests greater resilience than expected.

Audiovisual materials

We created six videos reflecting the diversity of species and the efforts made in conjunction with SAC-TUN for the conservation of wildlife.

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

This ECOSUR-Chetumal project is supported by SAC-TUN with the participation of SEMA's IBANQROO, the Federal Attorney's Office for Environmental Protection (PROFEPA), CONANP, Mexican Association of Habitats for the Interaction and Protection of Marine Mammals (AMHMAR) and the public who sent and continue to send us photos, videos and information about the manatees' movements and whereabouts.

Capturing and tagging manatees

In 2020-2021, we continued with our efforts to capture and tag manatees in the waters off the Quintana Roo coast.

Pancho, our visiting manatee from Florida, USA

We tagged our first manatee of 2021 in January in the waters off Isla Mujeres–a healthy adult male in good reproductive condition which we named Pancho. We took note of his size, health and reproductive condition, took a blood sample for genetic and clinical analysis, and provided him with both a heat and a satellite transmitter before his release.

Pancho's presence in Quintana Roo, together with that of another, as yet un-tagged, adult female manatee, confirms earlier, tangible, genetic evidence[4] that there are two sub-species of American manatee, one in Florida, USA, and the other in Mexico, Central America and the Antilles. Pancho's and the adult female's presence in Quintana Roo confirms the connectivity between these two sub-species and their free movements between the USA and other countries. It will be interesting to follow their routes, if and when they decide to return to Florida, to see if they go back via the Gulf of Mexico and Texas or instead travel by Cuba.

Tracking Pancho has provided us with detailed information about his movements, his exploration of the sites he has visited and his adaptation to a new environment since his arrival in Mexico.

[4] *Nourisson et al (2011).*

Although he lost his transmitter after three months when it was bitten off by a crocodile in the mangrove swamp in Tres Ríos, south of Playa del Carmen, we have been able to follow him thanks to the support of the public who send videos, photographs and notices of his presence, and he is still seen frequently in docks, marina channels and other urbanised coastal areas in Quintana Roo, including off the SAC-TUN pier, Akumal and Puerto Aventuras.

We retrieved Pancho's transmitter from the Tres Ríos mangrove swamp and are planning to reattach it at the earliest opportunity. We plan to search for and tag the adult female that also arrived from Florida.

We formed a citizen science group on the southern coast of the state for manatee photo-identification and opened a Facebook page for sharing information and videos about Pancho, other manatee sightings and our project in general. https://m.facebook.com/Pancho-el-manat%C3%AD-de-Florida-105246348272183/

Chetumal Bay captures and tagging

In May and September 2021, we spent six days in the Chetumal Bay Manatee Sanctuary–the area with the greatest presence of manatees and with shallow waters protected from the winds, which facilitate tagging activities. For the first time we used a drone to facilitate the detection and tracking of the manatees, which made the entire procedure more efficient.

In all, we tagged nine manatees, four females and five males, and with the assistance of AMHMAR's specialized veterinary personnel, took body measurements, recorded scars, noted the presence of malformations and parasites, assessed their muscle mass as an indicator of their health status, and took blood from eight of them (in one male it was not possible to find a vein). We then tagged four females and two

males with Global Positioning System (GPS) radio transmitters to track their movements and released them back into the bay.

To date, we continue to monitor three females, one of which moves frequently between Belize and the Chetumal Bay Manatee Sanctuary. However, there are transmission deficiencies in the radios installed on two of them and we have lost contact with the two males and one female: two because the transmitter came off and one because of equipment malfunction. We have contacted the supplier of the radio transmitters who acknowledges that the malfunctions are due to circuit errors that prevent the transmitters connecting to the satellite. The way to remedy this is to remove the transmitters and return them for repair which we plan to do at the earliest available opportunity.

The blood samples were clinically analysed and revealed that seven manatees were healthy but two had health problems, one a thin young male with signs of malnutrition that was captured and released for the first time in 2005, and the other a thin female (which we named Matilda) with a genital fibro-papillary lesion that requires resampling for the specific diagnosis of possible viral papilloma. Since 1994, and after evaluating a total of 81 manatees, Matilda is the first in the Mexican Caribbean manatee population to display this type of papillary lesion. This is of concern as it could be associated with the presence of emerging viral diseases with health effects that have not been evaluated for our manatee population. Matilda, who was also tagged, subsequently moved to Belize where our fellow park rangers and specialists there were planning to recapture her in January 2022 to carry out the necessary biological samplings and detailed clinical studies for a thorough diagnosis.

Data mapping for easy visualisation of manatee movements

We created maps monitoring Pancho's, Matilda's and the other manatees' movements and use of temporary habitat, as well as databases recording morphometric data, blood test results and any other analytical information. We also developed heat maps to show the density of occurrence of the locations of each manatee, which reveals their most important areas of use.

The transmitter that was installed on Pancho was bitten off by crocodiles in the Nichupté Lagoon and had to be repaired with fiberglass.

The heat maps clearly reflect that, for the Bay of Chetumal and the coast of Belize, manatees prefer coastal places with a freshwater presence and shelter from strong winds. Along the coasts of Quintana Roo, the lagoons, coves, cenotes with access to the sea, estuaries and the Hondo River offer these conditions.

This preference is very marked in Pancho's movements as he clearly chooses to shelter for rest or to drink fresh water very close to docks during the cleaning of boats, and has been seen close to different urban areas such as the cities of Chetumal and Calderitas in Mexico and Corozal in Belize, within the Chetumal Bay sanctuary and Bahía de Corozal, and elsewhere along the coast of Quintana Roo where there are important fishing ports and tourist and marine developments, such as Puerto Juárez, Puerto Cancún, Puerto Morelos, Puerto Aventuras, and real estate developments in different coves such as Xel-Há and cenotes such as Xpu-Há.

This shared use of the coastal zone between manatees and humans may represent a potential conflict.

Citizen science

At the end of 2019, managers of several dive houses reported sighting manatees on the south coast of Quintana Roo, between the towns of Majahual and Xcalak and in the waters of the Xcalak National Reef Park, all of which are important for this study. We provided the dive houses with registration forms and instructed them on the type of underwater photography required for the identification and sexing of the manatees observed during their tourist diving activities.

This has generated important results, including evidence in June 2021 of a mating group made up of nine manatees located a few kilometers south of the town of Majahual. Mating groups are notoriously difficult to observe in the wild and these citizen science photographers made an exceptional effort to obtain ventral images of all the manatees and their scars and cuts, which made it possible to identify a female in estrus (in a receptive state) surrounded by eight males seeking to copulate with her.

Other activities are being planned with this group of divers, such as the inclusion of students, to maintain their interest and contribution to the study of manatees in deep coastal waters.

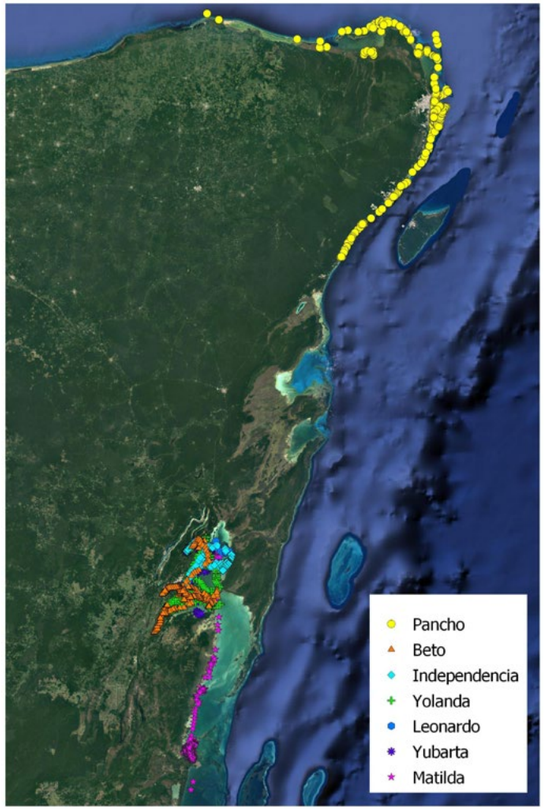
International manatee count

We held two work sessions with various specialists from Central America in which we agreed to estimate the manatee population in May 2022, including along the coasts of Quintana Roo, Belize and Guatemala.

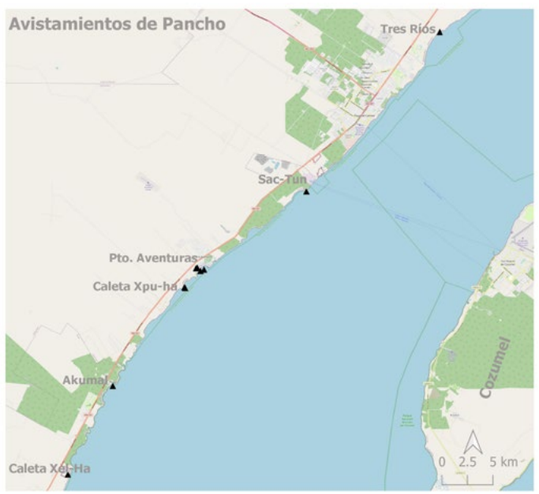
More information and photographs on the Quintana Roo manatees can be found in issue 73 of the May 2021 issue of *Sirenews*, the newsletter of the IUCN Sirenia Specialist Group.

Placing the radio transmitter on Pancho and subsequent release. Photos: Humberto Bahena/ECOSUR-Chetumal

A) Record of Pancho on 13 October 2021 off SAC-TUN, swimming fast to the south, at a depth of four meters; and (B) Pancho on 12 July 2021, recorded resting in the Xpu-Há cove. Note the characteristic scars on the caudal fin and the marking belt.



Areas used by Pancho and six more radio-tagged manatees in Chetumal Bay, Quintana Roo. The map reflects information gathered until November 2021



From May to October 2021, Pancho was seen using different coves, cenotes and marinas located between Playa del Carmen and the Xel-Há cove

Morphometric data collection: circumference at navel level; caudal fin length; and record of spots and scars on the caudal fin

Mating group showing female in estrus (center, gray manatee) and several males with verdigris (algae) on their body. The lack of verdigris on the female's skin indicates that she recently entered marine waters, unlike the males.

Pancho in Xel-Há natural cave in the Riviera Maya coast wearing his satellite transmitter belted on. Photo: Staff of Xel-Há Marine Park

CONTRIBUTION TO THE SUSTAINABLE MANAGEMENT OF WHALE SHARK TOURISM IN THE MEXICAN CARIBBEAN, 2019-2022

SAC-TUN has been supporting Pronatura Península de Yucatán, AC (PPY) since 2019 to develop carrying capacity models that will contribute to the sustainable management of whale shark tourism in different locations in Quintana Roo and further afield, so that the whale sharks, their habitat, and the people who depend on them for their livelihoods are able to thrive.

Since 2019, we have been monitoring whale shark populations to establish where and when they congregate in Quintana Roo, the number of boats per month that take tourists out to swim with them, and where they go.

Our overall goal is to use these data to create and compare two scenarios using different base variables (abundance of whale sharks *vs* boat utilization of ocean surface area) to determine the sustainable tourist load capacity.

We also aim to establish with the authorities the environmental, social, physical and management variables that will be integrated into the models to determine sustainable carrying capacity for tourism.

Monitoring overflights

In 2021, with the assistance of CONANP's staff member from the Mexican Caribbean Biosphere Reserve, we conducted six overflights covering a total distance of 2,399 km in almost 13 hours of flight time, during which we counted a total of 121 whale sharks, an average of 20 per flight. This was significantly lower than the average of 82 whale sharks spotted per flight in 2019 and 99 whale sharks per flight in 2020.

The maximum number of whale sharks spotted on any one day occurred in July 2021 when we counted 48 animals. This is significantly less than in 2019 and 2020 when more than 100 whale sharks were counted on at least two occasions.

Overall, in 2021 we spotted only 30% of the total numbers of whale sharks noted during overflights in 2020 (396) and 2019 (413). Decreases in the number of whale shark sightings per season in the area have already been reported in previous studies but the reasons for this are not yet clear. It may be related to the lack of available whale shark food. Habitat studies carried out for more than 15 years by PPY in coordination with the Center for Research and Advanced Studies (CINVESTAV) have shown that food is the factor with the greatest influence on the abundance of whale sharks in the area.

It is important to continue to carry out whale shark counts and assess the trends and changes in their abundance and, additionally, it has become clear that there is a need for data on the availability of whale shark food and to analyse this to help determine the causes of the decrease in the number of sightings.

The number of overflights in August 2021 was limited owing to bad weather and mechanical failures in both the plane and boats, and the unacceptably high costs of hiring alternatives. This may also have had some impact on the low number of whale sharks spotted this season since August is usually a month when large numbers are sighted.

Although the count in 2021 was not as high as in previous years, variations in abundance throughout the season were similar to those of the two previous seasons.

Number of tourist boats daily

Between 2019 and 2021 we carried out a total of 15 overflights in 32 hours over approximately 4,544 km^2 of the sea surface in which we spotted a total of 942 whale sharks. On average, we counted 70 tourist boats per flight day across the three seasons.

In 2021, we spotted an average of 83 tourist boats on each monitoring overflight, which is only slightly higher than the 79 boats spotted each day in 2019. In 2020, we spotted only 38

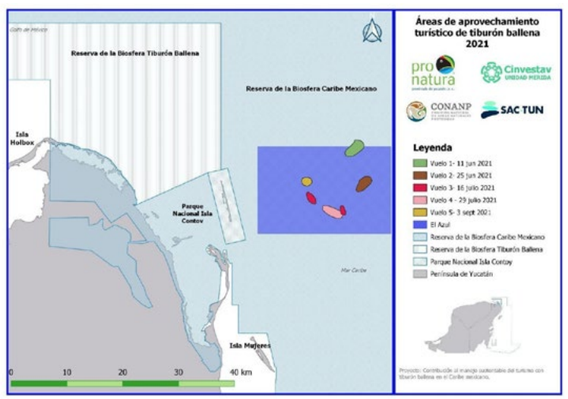
boats per overflight, significantly lower than in other years due to the COVID-19 pandemic restrictions, social distancing regulations and port closures which meant less boats were in operation.

Busiest months

In 2021, July was the month in which we spotted the largest numbers of both whale sharks and boats, which is not unexpected as July and August tend to be the busiest months for tourism. During the two overflights in July, the high number of vessels sighted exceeded the maximum permitted number established in the RBCM-CONANP Management Program (SEMARNAT-CONANP, 2019).

In September 2021, for unknown reasons, we spotted 30% more boats taking tourists to swim with whale sharks than in previous years.

The average surface area of the ocean used for whale shark tourism activities in 2021 was 4.38 km^2, similar to the area recorded in 2019 (3.96 km^2) and, in both cases, greater than that estimated in 2020 (2.2 km^2) when tourism was limited.



Is there a correlation between number of whale sharks spotted and surface area of ocean visited?

Although it might seem logical that a larger tourist use area means a greater number of whale sharks present, this is not necessarily correct.

To assess whether there is a relationship between the size of the estimated tourist use area and the number of registered whale sharks, we applied a statistical correlation analysis using the data from both variables. The results indicated that there is no correlation between the number of sharks and the size of the area used for tourism.

We can corroborate that, on certain occasions, large areas for tourist use have been recorded with a high abundance of sharks (July 2019), but we have also recorded large areas with few whale sharks (2021 season). This may be because the sharks were dispersed in a more extensive area, probably because their food was scattered, or the amount of food was lower than in previous years. Consequently, the boats also dispersed, occupying a larger area.

In the three study seasons (2019, 2020, 2021), the size of the tourist use area for whale sharks fluctuated between months, registering maximum values of 6.56 km^2 in June 2021 and minimum values of 1.44 km^2 in July 2020. The average tourist use area, the result of 15 overflights during three seasons, is 3.67 km^2.

Checking compliance with regulations

In coordination with CONANP, in 2021 we carried out seven marine monitoring trips between June and September to assess compliance with the five regulations established in the RBCM-CONANP Management Program (SEMARNAT-CONANP, 2019) for conducting tourist activity with whale sharks.

The five regulations are:

1. A tour guide for each visiting group, accompanying a maximum of two visitors at a time.
2. One boat per whale shark. Any other vessel must wait for the first to finish its activities. If both vessels agree, they may alternate in carrying out the activity. The rule states that a maximum of two tourists can swim with any one shark at the same time.
3. Maintain a distance from the whale shark no less than the length of the boat (10 meters).
4. Swimmers must maintain a minimum distance of five meters from the whale shark.
5. All users and group guides must wear life jackets.

It is important to note that, in practice, tourists often get closer to the whale sharks than the permitted five meters and, therefore, for this study, the minimum compliance distance was considered to be two meters.

We recorded information during swimmer/vessel/whale shark interactions during each sea tour. An *interaction* begins from the moment a boat approaches a whale shark so that tourists can enter the water to swim near it. The *interaction* ends when the whale shark is out of reach of the swimmers or when they return to their boat.

We collected data from 88 interactions between June and September and, from this information, calculated an average of 79% compliance with the rules. The use of life saver vests on board the boats was the only rule that was followed with 100% compliance. Rules regarding the numbers of boats per whale shark were only followed with 61% compliance and the rule on the number of tourists allowed to interact with the same whale shark was only followed with 51% compliance.

The highest compliance average (90%) was recorded during the first marine tour in June 2021, shortly after the start of the season. However, as the season progressed, this percentage decreased. The lowest average percentages of compliance (71%) were recorded on July 15 and September 2, days which coincided with a low number of whale sharks (13 and 10 whale sharks, respectively), and a high number of boats (85 and 123, respectively).

Even towards the end of the season on September 2, the maximum number of boats counted during the marine tour was higher than the permitted number.

Carrying capacity models

The two methodologies for calculating load capacity models were based on different base variables.

Model 1

Model 1 uses *abundance of whale sharks* as a base variable and also considers:

•The number of whale sharks counted per day (based on the supposition that the number of whale sharks present is the main factor for the development of the activity).

•The number of tourists who want to swim with the whale sharks (the rule being one whale shark to two swimming tourists).

•The number of groups that can do the activity in any one day.

•The amount of time it takes to get to the sighting area (an average of 70 minutes in 2021).

Model 2

Model 2 *takes the area of tourist* otal area for the development of the activity (the entire 400 m^2 of the El Azul area which, although it is not officially decreed, has recorded high number of whale sharks in recent years).

Area for tourist use (based on the assumption that whale sharks are not present everywhere but instead appear in smaller "patches". This variable is currently estimated based on monitoring overflights).

Number of boats that can interact with the whale sharks per day (taking into account the number of tourists on each boat, how long it takes each tourist to have two occasions to swim with the whale sharks, and how long each boat is permitted to stay with each whale shark according to the management documents).

Both models also take into account the following variables:

•The numbers of days without activity (due to bad weather, closed ports, rest days, etc).

•Average percentage compliance with the rules (an average of 79% in 2021).

•Number of surveillance days in the area (54.8%).

•Infrastructure, equipment and personnel for surveillance (given that this is difficult to calculate, it was assumed that there was full compliance for this variable).

The results from both models were similar. With model 1, a result of 1,099 tourists per day was obtained, the equivalent of approximately 110 boats. With model 2, the result is 1,072 tourists per day, or approximately 107 boats. The currently established cargo capacity is 120 boats per day, which is 1,200 tourists if all boats carry the maximum 10 authorized passengers.

Other significant activities in whale shark conservation

Cancellation of Navy plans for target practice around Isla Contoy

In January 2021, the Secretary of the Navy was planning to carry out target practice in February in the eastern area of Isla Contoy, north of Isla Mujeres. This area is located within the El Azul and is not only a critical habitat for whale sharks in the Mexican Caribbean but is also highly important for sea turtles and various species of other fauna that inhabit this region.

In support of the Isla Contoy-CONANP National Park, PPY prepared a document with information on the importance of the area for various species, including whale sharks, highlighting their economic and ecological importance and the risk of potential impacts derived from the planned Naval activities. This report was sent to the Isla Contoy National Park management to request the Secretary of the Navy to reconsider the planned activity. In February, a statement was issued informing that this activity had been cancelled.

Advisory Council of the Whale Shark Biosphere Reserve (RBTB-CONANP)

In March 2021, PPY participated in the first meeting for the formation of the Advisory Council of the Whale Shark Biosphere Reserve. One issue addressed was the unequal distribution of permits for whale shark tourism between Holbox Island and Cancun. Interest was also expressed in increasing the number of permits for whale shark activity for Holbox tourist service providers. We agreed to inform this authority of the results of our load capacity model calculations.

Third Encounter with a Whale Shark virtual event

In June 2021, the third Encounter with a Whale Shark virtual event took place to promote the exchange of experiences, lessons learned and challenges of carrying out whale shark tourism activities in the Mexican Caribbean.

This forum considered the perspectives of various social sectors with interest in whale sharks and whale shark tourism, and identified seven issues of importance for their sustainability, each with its respective challenges.

The event reached an estimated 4,913 people and was organised by PPY in coordination with the Mexican Caribbean Biosphere Reserve-CONANP and SustenTur consultants. Participating government institutions included CONANP, Quintana Roo Secretariat for Tourism (SEDETUR), SEMA, State Tourism Promotion Council, and some service providers.

International Day of the Whale Shark photo exhibition and virtual tour.

We commemorated the International Day of the Whale Shark (August 30) with a virtual photographic exhibition and a virtual guided tour to inform viewers about whale sharks, supportive actions to support their conservation, and to promote responsible whale shark tourism. This event, which was inaugurated on August 26 and has reached an estimated 10,000 people, was organised by PPY in coordination with the Mexican Caribbean Biosphere Reserve-CONANP and with the support of well-known regional photographers. The exhibition is still active for your visit at:
https://www.artsteps.com/view/612035f75f70ed052161d609

Whale Shark Biosphere Reserve

This protected natural area is not only important for whale sharks but is also relevant for the migration, reproduction, nesting and growth of commercially important crustaceans such as several species of shrimp and spiny lobster *(Panulirus argus)*, a transit area for turtle migration, an endangered species; as well as important groups of manta rays *(Manta birostris)* and eagle ray *(Aetobatus narinari)*.

CONSERVATION OF CRITICAL SEA TURTLE NESTING HABITATS, CONNECTIVITY AND POPULATION PARAMETERS, IN THE NORTHEAST OF THE YUCATAN PENINSULA, 2019-2022

SAC-TUN, SEMARNAT, CONANP and other partners[5] have been working with Pronatura Península de Yucatán with this project this project since 2019. Our aim is to monitor, count and protect the populations of hawksbill and green sea turtles that feed and nest on Quintana Roo's El Cuyo and Holbox beaches, which are recognised internationally as critically important habitats for these endangered species.

In 2021, we continued to monitor and protect 49 km of beach, 24 km in Holbox Island and 25 km in El Cuyo. Both beaches are considered among the 14 most important for hawksbill and green turtle nesting in the Atlantic and, as index beaches, are used as thermometers for the recovery of the populations of these species and some of their reproductive parameters.

On El Cuyo, in 2021, we counted 713 hawksbill nests and 3,152 green turtle nests. On Holbox, we counted 1,409 hawksbill turtle nests–a new historical maximum–and 523 green turtle nests. For both species, this is higher than the annual average (2,234 ± 2,096.57).

From these nests, 188,079 hawksbill and 336,836 green turtle hatchlings were released. Between April and October 2021, we tagged a total of 172 neophyte females and identified 25 females that we had tagged in earlier years (recaptures). Two females were first tagged more than two decades ago: the first is a green turtle that was tagged in 1995 in El Cuyo, was observed in 1997 in Las Coloradas and was observed this year nesting in El Cuyo again. The second female is a hawksbill turtle that was tagged in 1998 in Las Coloradas and was recorded in 2017 and 2021 in El Cuyo.

Recapture data demonstrate strong nesting site fidelity as only 14.28% of observed females had tags from other beaches.

The breeding population of hawksbill turtles in this area continues to grow, particularly on Holbox beach. The ratio of tagged neophytes to recaptured female hawksbill turtles was 13:1 in Holbox and 3:1 in El Cuyo. This is higher than the previous season, increasing by 3.5 times in Holbox and 50% in El Cuyo.

The proportion of tagged neophytes to recaptured female green turtles was 15:1 in El Cuyo and 11:1 in Holbox. The proportion of neophytes increased by 7.14% in El Cuyo but decreased by 21.4% in Holbox. As with the hawksbill turtle, an increase in the proportion of neophyte female green turtles is indicative of the growth of the breeding population. However, the marking effort can also affect these proportions, so it is necessary to keep marking activities constant over time. In Holbox, this was not possible in 2021 due to port closures for climatic reasons that limited both tagging and observation of females. A new strategy is being evaluated so that we can maintain a constant effort in the coming seasons.

In March 2021, we planned our tissue collection calendar for the year to avoid taking samples from the same female twice. We agreed to collect samples from 10 females of each species on both beaches during the week of the 15th day of each month. In total, we made six collections during which we took samples from 100 green turtles and 70 hawksbills. We added these to the samples taken from female turtles in 2020 to make a total of 207 samples that are ready for genetic analysis and to determine the connectivity of their critical habitats. These samples will be sent for analysis once we receive the necessary CITES export permit.

Due to storms and threats of hurricanes, Holbox port was closed to navigation for 63 days during the nesting season which limited our beach monitoring days to 65. Although this did not affect the recording of nests, it did affect our efforts to mark and recapture females. We are working on developing a strategy to increase the marking effort in coming seasons.

Accumulated results from three years of activities

From 300 days of monitoring between 2019 and 2021, we registered and protected 19,823 nests, 4,733 from hawksbill turtles and 15,090 from green turtles.

The average annual growth rate for hawksbill turtle nests increased in El Cuyo from 7.15% in 2019 to 7.93% in 2021 and in Holbox from 7.48% in 2019 to 8.08% in 2021.

The average annual growth rate for nests from green turtles *decreased* over the same period, from 14.34% in 2019 to 13.23% in El Cuyo, and from 14.86% in 2019 to 12.39% in Holbox in 2021. However, the number of nests continues to be above the long-term annual average of 1,134 green turtle nests in El Cuyo, and 227 in Holbox, so we do not consider this decrease in rate of population increase to be due to a reduction in the breeding population, but rather to changes in their nesting patterns.

Over the same time frame, we temporarily caught and tagged a total of 396 females, and caught another 277 previously tagged females, including five female recaptures (three hawksbill and two green) that have been nesting for more than 20 years in this region of the peninsula.

Recapturing female turtles provides a new opportunity to learn more about the reproductive age of these species and the effectiveness of marking. According to previous studies, the average age of sexual maturity of hawksbill turtles in the Caribbean is 20 years, so our recaptured hawksbill females must be between 40 and 45 years old. The age of sexual maturity of the green turtle is between 20 and 40 years.

These data highlight the importance of long-term monitoring of nesting beaches as an important tool in improving our understanding of the reproductive age of female turtles in this region.

Green turtle nesting habits

The green turtle nests every two or three years, depending on the quality and availability of food, and this is reflected in years in which nesting is very high (2019), followed by one or two seasons of low nesting. On El Cuyo, another influential factor is the movement of females to the adjoining beach of Las Coloradas. In previous years, we have observed that the highest nesting density fluctuates from one season to another between the east beach of Las Coloradas and the west beach of El Cuyo. It would be interesting to know the nesting results of this species in Las Coloradas to see if this pattern is still maintained.

Hatchling release

During the 2019-2021 period, 1,276,770 sea turtle hatchlings were released on these two beaches, of which it is estimated that 362,243 were hawksbill hatchlings and 910,527 green turtle hatchlings.

Maintaining high hatchling production through monitoring and protecting nests will continue to be critical to increasing sea turtle populations in the region and maintaining a breeding population growth trend.

5 CONANP, Río Lagartos Biosphere Reserve, Yum Balam Flora and Fauna Nature Reserve, SEE Turtles Organisation, and Edmund and Joann Andrews

Nesting density

An estimate was made of the nesting density of each sea turtle species using satellite data to create spatial modules with a resolution of 10 meters per pixel showing the geographical distribution of nest density per square kilometer. The resulting models were compared with those of 2019 and 2020 to observe the spatial variation of density between seasons.

At El Cuyo beach, changes were observed in the distribution of hawksbill nest density between the three seasons. In 2019 and 2021, the highest density was concentrated on the east beach where more than 60% of the nests were recorded. Only in 2020 was a homogeneous distribution of nests observed on the east and west beaches due to a higher amount of rainfall that influenced nest site selection.

The highest density of green turtle nests remained on the west beach during the three seasons. In 2021, 96.09% of this species' nests were recorded on the west side of the beach, even though some kilometers there were eroded.

These results highlight the importance of both segments of El Cuyo beach for the two species of sea turtle and the need to approach the management of these beaches in a different way, since their threats are different. On the east side, the greatest threat is tourism development that mainly affects hawksbill turtles, while on the west side, beach erosion is more important and affects green turtle nesting.

In Holbox, changes were observed in the distribution of nest density of both species. In 2019 and 2021, the distribution of hawksbill nests was homogeneous throughout the 24 km of monitoring, while in 2020 it was concentrated in the middle part of the beach. This difference could be due to the increase in precipitation observed in 2020 that altered the humidity of the sand.

The pattern of green turtle nest density was similar in all three seasons, with a higher density at the eastern end of the beach.

On both beaches, from 2019-2021, both species of sea turtles displayed a marked preference for the dune area of the beaches for laying their eggs. In El Cuyo, 65% of the hawksbill and 84% green turtle eggs were laid in the dune area. In Holbox, 86.6% of hawksbill and 93.3% green eggs were laid in the same area.

In El Cuyo, some parts of the beach have not recovered from the 2020 hurricanes, so it is important to consider dune restoration actions that both favor the nesting of these species and increase the protection of the coastal community.

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

SAC-TUN, together with CReW+[6] and the Gonzalo Río Arronte Foundation[7], is supporting Amigos de Sian Ka'an in integrating Mayan communities, students, and tourism operators in the conservation and proper use of freshwater aquifer and cenote resources in 22 Maya Ka'an and Riviera Maya communities.

This project aligns with the State Plan for Environmental Education of the State of Quintana Roo (PEAA) 2020-2022 and with SEMA work schemes, particularly the strategic lines: 1. Formal environmental education; 2. Non-formal environmental education; 4. Training in rural areas; and 5. Training in business.

In the earlier, first phase of this project (2014-2018), 347 eco-technologies (bicycle-powered water pumps, water cisterns, composting toilets, solar panels, etc) were installed in individual dwellings or in communal areas in 12 Mayan communities in the municipalities of Felipe Carrillo Puerto, Tulum and José María Morelos in Quintana Roo, benefiting 1,042 people. A subsequent evaluation showed that 35.5% of these eco-technologies had been successfully assimilated and were still being used by the communities.

We learned important lessons from the first phase which guided us in implementing the second phase of the project in 2020-2021, aiming for greater appropriation and acceptance of the eco-technologies within the communities. These lessons learned include the need for:

Preparing a socio-cultural-technical diagnosis of each community.

Preparing a catalogue of eco-technologies that respond to the geographical conditions of the region.

Installing the selected eco-technology in strategic locations.

Selecting eco-technologies that are affordable, easy to use and durable.

Capacity building within the community to ensure understanding of the benefits of the eco-technology.

Training local managers to administer and maintain the eco-technologies.

Taking into account costs, time and effort required to maintain the eco-technologies.

Ensuring local managers have an adequate administration system.

In SAC-TUN's second year supporting this project, and despite a year in which the COVID-19 pandemic prevented visits to the Maya Ka'an and Riviera Maya communities we are assisting, Amigos de Sian Ka'an was very active and succeeded in:

Preparing a training manual to improve the capacity of the Amigos de Sian Ka'an work teams to conduct socio-environmental and technical diagnoses in local communities, and to develop strong relationships with and train local beneficiaries to play an active role in the sustainable development, protection and integrated management of their community's freshwater resources and ecosystems.

Conducting socio-environmental and technical diagnoses in eight Maya Ka'an communities to identify opportunities, risks and a logical route for the implementation of the Strategy to Strengthen Community Water Governance.

Designing a catalogue of sustainable eco-technologies that are suitable for implementation in the 22 Mayan communities.

Supporting 24 students from the Tulum College of Scientific and Technological Studies in water quality monitoring for eight months (from February to May 2020 and from November 2020 to April 2021) as well as advancing the Environmental Education Program for the Promotion of Water Culture with online classes.

Supporting three Maya Ka'an schools in the communities of Tabi, Yaxley and Yodzonot Nuevo in the municipality of Felipe Carrillo Puerto, Quintana Roo, in initiating their Citizen Science Program and the Environmental Education Program for the Promotion of Water Culture.

Designing the approach towards implementing the Strategy to Strengthen Community Water Governance in Tabi, Yaxley and Yodzonot Nuevo and starting construction of rainwater harvesting cisterns in these three communities.

In alliance with SEDETUR, facilitating the participation of six community, nature tourism companies from Maya Ka'an in the training in Tourism Hygiene and Quality Protocols.

Training 29 treatment plant operators to complete the 2nd edition of the Diploma in Adequate Management of Wastewater Treatment Plants as a tool to improve the health of the Mesoamerican Barrier Reef System, which was taught in collaboration with the National Autonomous University of México (UNAM) Engineering Institute.

Collaborating with the University of the Caribbean (UNICARIBE) on a Diploma for Environmental Education in the Mexican Southeast directed towards Maya Ka'an teachers. In September 2021, five teachers from Maya Ka'an participated in the 3rd edition of this diploma.

Cenotes

Cenotes are freshwater sinkholes that naturally occur in the limestone bedrock and are an important source of potable water for many rural communities, as well as a great tourist attraction. They are also a spectacular feature of the Yucatan Peninsula, traditionally representing the doorway to the magic water world of Xibalbá.

The main threats facing cenotes are increasing contamination from untreated wastewaters that drain directly into the aquifer, lack of management of solid wastes, potential future over-exploitation of limited freshwater resources and climate change.

Conducting socio-environmental and technical diagnoses

Between May and October 2021, a socio-environmental analysis, technical survey and diagnostic study were carried out by a team of engineers and architects in eight communities in Maya Ka'an, namely Tabi, Yodzonot Nuevo, Hobompich, Yaxley, Dzaptún, San Antonio Segundo, Yaxche Chal, Los Lagartos, Santo Domingo, Tzukum and Sahcabchén, with a total population of 1,184 inhabitants.

These provided relevant information about community organization, highlighted the communities' main problems with water, and clarified their prior knowledge and perception about eco-technologies, water management, hygiene and health.

Based on this, we were able to identify opportunities and risks and prepare a logical route for the implementation of our Strategy to Strengthen Community Water Governance (EFGHC). Work began in the eight communities in December 2021, along with the construction of some of the selected eco-technologies (rainwater harvesting cisterns).

Workshops were also held in each location to introduce local schools and students to the concept of citizen monitoring of water quality and the *You are Water*, Be Aware! campaign.

Catalogue of sustainable eco-technologies

Developing this catalogue represents an important step towards successfully implementing the Strategy to Strengthen Community Water Governance.

The catalogue was developed in two virtual workshops held in February 2021 in collaboration with the Quintana Roo Secretariat of Social Development (SEDESO) and with the participation of experts in eco-technologies and in project development. These experts considered lessons learned in an evaluation of the earlier project (2014-2018) which showed that 35.5% of the eco-technologies installed were appropriated by the inhabitants of the communities and took into account the eight recommendations for the future steps to be taken to ensure community acceptance, use and appropriation of the eco-technologies installed.

[6] *CReW+ is the Integrated Approach to Water and Wastewater Management Using Innovative Solutions and Promoting Financing Mechanisms in the Wider Caribbean Region, which is a is a program of the Global Environment Facility (GEF) 2019.*

[7] *The Gonzalo Río Arronte Foundation is a non-governmental organization founded in 2002 that supports social projects related to health, addiction and water.*

Workshop participants evaluated 34 different eco-technologies according to 18 criteria such as cost, maintenance needs, ease of use, design and construction, safety, etc. The 12 eco-technologies that were ultimately selected for inclusion in the Catalogue were deemed most appropriate for the specific conditions of the 22 communities of Maya Ka'an and include water filter mechanisms, rainwater harvesting systems and cisterns, hand washing facilities in schools, composting toilets, biodigesters, water storage tanks, waste-water treatment areas, and solar water heaters. Catalogue of Eco-Technologies.

Citizen science program, water quality monitoring and the environmental education program for the promotion of water culture

Remote and marginalized communities in Quintana Roo depend on freshwater sourced in cenotes and aquifers for their daily domestic needs. Monitoring the quality of this water is fundamental to know if it is healthy for both human consumption and the ecosystem, to know the relationship between water quality and the activities that are carried out in adjacent areas, and to clarify which areas have the poorest quality of water.

This program aims to encourage communities to take an active role in scientifically examining the state of their local environment and freshwater resources and in developing plans to monitor and improve their management, where necessary.

Amigos de Sian Ka'an, with the support of SAC-TUN, has developed an educational program for teachers and students from both primary and secondary schools that raises awareness of the importance of cenotes, wells, and aquifers and the local ecosystem, and the need to care for them. An intrinsic part of this is for students to develop water monitoring systems of their local freshwater supply that can generate useful information for managing these facilities and better caring for and conserving water.

In November 2021, three teachers and 38 students (50% female and 50% male) from three schools8 in Tabi, Yaxley and Yodzonot Nuevo in the municipality of Felipe Carrillo Puerto, Quintana Roo, participated in our You are Water, Be Aware! workshops as a precursor to beginning our Environmental Education Program for the Promotion of Water Culture and the first step towards implementing our Strategy to Strengthen Community Water Governance.

Diagnostic workshops were also held in the Yaxely and Yodxonot Nuevo schools to establish a baseline of students' knowledge and perceptions of cenotes and water management issues in their schools and communities.

Following the workshops, the students proposed a pilot Citizen Science Program to monitor water quality in their homes and schools to determine if their tap water is drinkable, based on the parameters used in the sampling methods.

Instagram posts made by students from the State College of Scientific and Technological Studies (CECyTE) Tulum to promote the care of the cenotes and their water.

[8]*The Álvaro Obregón Elementary School in Yodzonot Nuevo (9-10 years), the Telesecundaria Jacinto Pat in Tabi (13-14 years) and the Telebachillerato in Yaxley (16-18 years).*

Training in Tourism Hygiene and Quality Protocols

In September 2020, Amigos de Sian Ka'an/SAC-TUN began to collaborate with SEDETUR to teach the Training for Nature Tourism Companies in Comprehensive Management of Cenotes and Springs course. The aim is to increase the capacity of nature tourism companies in comprehensive, sustainable management of cenotes, caves and springs to minimize polluting activities and protect the potability and salubrity of these freshwater resources.

Following the reopening of the tourism industry after the COVID-19 shut-down, a second, online *Training Program in Tourism Hygiene and Quality Protocols* was added in February to April 2021. The 20-hour course was designed to support tourism companies in creating and implementing hygiene protocols for the safety of their collaborators, tourists and the communities in which they operate, as well as prevention measures that avoid impacting the environment, and the application of good practices in the care of water.

As part of the course, participants identified and designed a sanitary protocol that fits their nature tourism activities and is aligned with water care, mainly in the adequate and rational use of chemical products for cleaning and disinfection. These good tourist practices in cenotes are complementary to, and an integral part of, the sanitary requirements imposed by COVID-19.

Six community nature tourism companies[9] from Maya Ka'an took part with a total of 19 people completing the training, 13 from 10 tourism companies and, six from community companies in the Maya Ka'an region.

Diploma in Adequate Management of Wastewater Treatment Plants as a tool to improve the health of the Mesoamerican Barrier Reef System.

The 1st edition of the Diploma in Proper Management of Wastewater Treatment Plants as a tool to improve the health of the Mesoamerican Barrier Reef System was a great success in 2019. Consequently, between August and October 2021, Amigos de Sian Ka'an collaborated with the UNAM Engineering Institute to train a further 29 wastewater treatment plant operators in completing the 2nd edition of this 120-hour-long program. Twenty-two participants succeeded in passing the course which makes a total of 57 operators who have now been trained in the correct handling of water treatment plants in Quintana Roo[10].

[9]*Beéj Kaáx Ha Kantemo, Balam Nah, Siijil Noh Ha, Orchids of Sian Ka'an, Ubelilek and Tourists of Vigia Grande.*

[10]*These include several hotels, the Commission for Potable Water and Sewage (CAPA), the Municipalities of Solidaridad and Tulum, SEMARNAT and companies such as AGUAKAN, Agromaizza, Keken and the wastewater plant operator at the Chetumal International Airport.*

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

Since 2019, SAC-TUN has been supporting Community and Biodiversity (COBI) with this project which supports six of the major fishing cooperatives in three of the largest protected fishing areas of the Yucatan Peninsula to develop an innovative, sustainable fisheries sector.

In the second half of year two of this project, we were able to make substantive progress in some key tasks in the Sian Ka'an Biosphere Reserve and the Sian Ka'an reefs after we resumed field activities that had been stalled during the COVID-19 pandemic.

We continued with fish and ocean water sampling and monitoring ocean parameters for temperature, sea level and currents at key spawning sites, and to take acoustic readings of fish activity. To facilitate this, we provided two air compressors and virtually trained 74 community partners in the use of oceanographic instruments to measure temperature, current, sea level, and acoustics, and in sampling for fish tissue and environmental DNA, as well as offering virtual and in-field training on diving skills, dive safety, and sensor data download.

The data sensors will allow tracking with our remote support during the spawning season in the spawning aggregations (December 2021 to March 2022). In addition, we will continue to support the communities by lending the rest of the equipment necessary for autonomous diving.

Resumption of field trips and underwater monitoring

In September and October 2021, we resumed our field trips, collaborating with 17 fishers (14 men and three women) from the Punta Allen and María Elena communities. Our community partners are using state-of-the-art technology to study genetic connectivity and are committed and proactive, proposing complementary activities so that we could expand the diversity of samples collected.

In Punta Allen, with the supervision and guidance of COBI staff, our partners organized the field work logistics, forming mixed teams, sharing leadership in planning, logistics, diving safety, data entry and equipment management tasks, and challenging social constructs of gender-based division of labor–for example, a woman operates the tank compressor in the community of Punta Allen. One woman and one man from Punta Allen travelled to the neighbouring community of María Elena to support monitoring there.

This framework promotes the commitment and responsibility of community members, empowering leadership. As a result, eleven monitors from Punta Allen (three women, eight men) have led monitoring of biological, acoustic and genetic connectivity.

In María Elena, eight community divers (six women and two men) resumed the biophysical monitoring of the protected fishing zone, collecting fish and invertebrate data from six polygons inside the zone and three control sites outside. We recorded 1,030 invertebrates and 5,015 fish in different sizes. Of the total records of monitored organisms, 44% correspond to species of commercial importance (e.g., lobsters, fish), and 56% to species of ecological importance (e.g., seagrasses, corals).

We collected 12 environmental DNA samples from four sites (six inside the spawning aggregation sites, five in control sites outside the aggregation sites and one negative control), bringing tissues samples of environmental DNA collected to date to 28. The new samples were preserved in our four Niskin bottles (funded with SAC-TUN donations) before being sent for analysis.

We also collected tissue samples from Caribbean grouper *(Epinephelus striatus)*,[11] bringing tissue collections to date to a total of 19, all of which come from individuals captured by fishers outside the fishing refuge areas.

In addition, we recovered 75,343 temperature and sea level measurements from two underwater sensors. Currently five underwater sensors are recording data.

Two other communities from Punta Herrero and Banco Chinchorro from the Sian Ka'an Biosphere Reserve and Sian Ka'an reefs have also participated in the download of temperature sensor data.

The four fishing communities of Punta Allen, María Elena, Punta Herrero and Banco Chinchorro are to be commended for successfully continuing their in-field investigations, acting both as citizen scientists and demonstrating their abilities for planning, leadership and shared responsibilities.

Lobster tagging

In 2021, we tagged 487 lobsters (*Panulirus argus*) in two fishing concessions in Sian Ka'an (334 in Punta Allen, 153 in María Elena), of which 24 (5%) were recaptured lobsters (23 in Punta Allen and one in María Elena). The mobility demonstrated by the lobsters varied from individuals that travelled more than one km in 10 days to others that did not move from the place where they were captured the first time. One recaptured lobster was not yet of commercial size, so it was released. Most of them were females. An important observation is that 51% of the tagged female lobsters presented a patch or spawn[12] which could be an indication that they are reproducing within protected fishing concessions.

[11]Categorized as "Critically Endangered" on the IUCN red list.

[12]Like other decapods, female lobsters carry the eggs attached between the abdomen and the telson (tail). When the sperm sac is in an early stage of development, fishers call them "patched females". When the eggs are in an advanced stage of development, close to spawning, they are called "egg females". In both cases, their extraction is prohibited according to the management plan for the spiny lobster in the Yucatan Peninsula (DOF, 2014).

PCR tests for fish

A PCR test designed in 2020 will make it possible to identify Caribbean grouper DNA in water samples. This test seeks to create an innovative method to estimate the abundance of groupers based on the genetic load of the species in the water sample. Environmental DNA sequencing results detected reef, cryptic, pelagic, and demersal species, demonstrating the ability of environmental DNA to characterize complex marine ecosystems. This is possible even when the visibility conditions of the site are not good and make it difficult, or even prevent, diving to monitor aggregations.

However, the lack of sequences in the GenBank[13] databases of species from the Mexican Caribbean is an important limitation and meant that few taxa could be identified at the species level, with most identifications made only to the genus or family level. We recommend starting a collection of tissue samples of commercial species or species of ecological interest from the Mexican Caribbean to build a local reference base of sequences that would allow us to improve identifications at the species level.

To do this, in addition to collaborating with the University of Arizona in the USA, we participate in the MARFish[14] network for reproductive fish aggregations in which we are collaborating with ECOSUR-Chetumal to exchange information and optimize resources. This will facilitate the expansion of the first environmental DNA study carried out in the Mexican Caribbean on ecological connectivity, with communities producing citizen science.

Passive acoustic monitoring data

We recovered 126 hours of passive acoustic monitoring records taken between March and May 2020 which, once analyzed, will allow us to determine the presence of groupers at the spawning site. We are collaborating with Florida Atlantic University to decipher and filter the acoustic data. The first analyses have yielded interesting preliminary results: it appears that Mexican Caribbean groupers have a higher pitch (shorter wavelength) than their peers in other Caribbean and Atlantic regions. We will confirm this hypothesis with the new records generated between December 2021 and March 2022.

[13] https://www.ncbi.nlm.nih.gov/genbank/

[14] *MARFish is a transnational initiative at the level of the Mesoamerican Reef System, supported by MARFund.*

Characterizing a potential site of reproductive aggregation at El Blanquizal in the Xcalak Reef National Park

In November 2021, we initiated a new line of research to characterize a potential site of reproductive aggregation in the Xcalak Reef National Park where we installed a hydrophone and temperature sensor at the site known as El Blanquizal. This may be a multi-specific spawning aggregation site since three species of grouper *(Epinephelus striatus, Mycteroperca bonaci* and *Mycteroperca tigris)* all use this site to spawn during the season.

In previous monitoring from 2014, it was estimated that the aggregation could be as large as the Punta Allen aggregation (>1,000 groupers). The installation of the hydrophone and temperature sensors will enable us to collect passive acoustic monitoring and sea temperature data as well as DNA information from this site for the first time. Data to be collected between December 2021 and March 2022 will help determine the presence/absence, as well as the size of the aggregation, allowing us to validate our estimates.

Members of the Vigía Chico cooperative monitoring group from Punta Allen, researchers from the Technological Institute of Chetumal, personnel from the Xcalak Reefs National Park, as well as the Andrés Quintana Roo cooperative (Xcalak) participated in this activity.

Knowledge sharing

Another of our goals in 2021 was to increase knowledge sharing between different fishing communities across the Mesoamerican Reef and throughout Mexico.

Fifteen community monitors (five women, 10 men) from Punta Allen, María Elena, Xcalak and Banco Chinchorro, participate in a network of fisher communities in Mexico. The network has a common vision and fosters collective action through mutually reinforcing collaboration. For example, on the network, community monitors shared their knowledge acquired in the virtual training on oceanographic and biological monitoring and sensor data download, passing on information about the sensors used and adaptations implemented to fix or hide the sensors, etc. The network thus seeks to incubate and accelerate solutions to scale its impact.

Members continue to meet every two months to share their daily solutions at work, building connections through a WhatsApp chat which will migrate to the mobile application designed by and for fishers ***(PescaData[15])*** during the first quarter of 2022.

Thematic groups have been implemented at the national level, including oceanographic monitoring and community monitoring.[16] This group includes 26 nationwide fishers (30% women) who are working to update the National Participatory Oceanographic Monitoring Protocol, which will include genetic connectivity.

Documenting solutions to fishing challenges

In July 2021, we finalized our data collection activities[17] to document solutions that individuals and communities in Quintana Roo are finding to resolve the challenges and changes that confront the modern fishing industry. This is a key component of our pioneering study of the connectivity of commercially valuable fishery resources in the Mexican Caribbean.

Six of the community solutions that have been implemented by COBI in collaboration with community partners such as SAC-TUN between 2020 and 2021 were incorporated on to the Panorama Solutions internet platform. Four of these solutions include the experiences and lessons learned in the Mexican Caribbean (Marine Reserves, Citizen Science, Technological Innovation, Recovery of ecosystems through collective action), with each solution containing four or five components that describe in detail the actions taken. Solutions published on *Panorama Solutions.*

In addition, we are creating digital catalogues of solutions that can be consulted online by all fishers throughout Mexico and elsewhere, as well as open-access galleries[19] showing successful adaptation activities. So far, we have documented 40 solutions nationally of which seven were developed in the Yucatan Peninsula. These solutions will soon be incorporated into the PescaData mobile phone application. Examples of adaptation solutions include unity and commitment in a cooperative, no-fishing zones, tourist cooperatives formed by women and waste collection centers. Community Solutions Digital Gallery.

With the support of SAC-TUN we were able to conduct eight months of fisheries' consultations in the Mexican Caribbean, including 1,500 interviews and 450 participants.

Based on these consultations, we had two articles published: the first in the September 2021 edition of the journal *Marine Policy entitled: The voice of Mexican small-scale fishers in times of COVID-19: Impacts, responses, and digital divide[20];* and the second, which was written in collaboration with researchers from ECOSUR-Chetumal, the Michoacán College and the Autonomous University of Baja California, in the November 2021 edition of Ambio entitled: *Between uncertainty and hope: young leaders as agents of change in sustainable small-scale fisheries[21].*

Next year, in collaboration with academia and communities, we will integrate the data on social and ecological connectivity information in Sian Ka'an, and we will replicate the study of social connectivity in the Banco Chinchorro Biosphere Reserve so that we can start generating social data in this protected natural area. This will allow, in the future, for information sharing between the two reserve areas.

The resilience of a community is related, in part, to the inter-connections they establish both between themselves and with other communities outside. A strengthened community that fosters routes for connection between its members, as well as with other communities, has more opportunities to exchange key knowledge for community resilience and improve their fishing practices to contribute to healthy oceans. We will continue to support this gradual process of empowering communities and we will continue our efforts to strengthen the social fabric so that more communities can get involved in marine conservation and sustainable fisheries and assume more responsibilities for their natural resources.

[15] *www.pescadata.org*

[16] *https://pescadata.org/community-monitoring-group-of-marine-reserves/*

[17] *We collected data on 83 challenges confronting the fishermen and fisherwomen from the Sian Ka'an Natural Protected Areas complex, Banco Chinchorro Biosphere Reserve, Xcalak Reed National Park and the Cozumel Protected Natural Areas complex in a face-to-face workshop in 2019.*

[18] *A solution is a product, project or service that helps coastal communities adapt and become more resilient to global and short-term changes. The solutions increase the resilience of communities, without compromising the health of the oceans. An adaptation action is that community action that is carried out to increase the resilience of communities and the health of the oceans, that is in the process of being implemented, but has not been replicated or demonstrated its effectiveness and that has the potential to become a solution.*

[19] *https://airtable.com/shry4PF4T5FEWeIMZ/tblL3OfmE45OM9GAL*

[20] *https://www.sciencedirect.com/science/article/pii/S0308597X21002177*

[21] *Between_uncertainty_and_hope_Young_leaders_as_agents_of_change_in_sustainable_small-scale_fisheries*

STRENGTHENING OF THE MANATEE LAGOON NATURAL PROTECTED AREA 2019-2022

Since 2019, SACTUN has been supporting SEMA's IBANQROO and ECOSUR with the project entitled Strengthening of the Manatee Lagoon Natural Protected Area.

The aim is to gather data that will lead to stronger measures for the conservation and protection of this important, transit zone ecosystem which serves as a shelter and nursery habitat for the reproduction of fish and crocodiles and offers potential for the creation of new sustainable livelihoods for local populations.

During 2020-2021, biological monitoring activities focussed on determining the composition, abundance and spatial distribution of fish and swamp crocodile communities associated with the Manatee lagoon system and on investigating their habitats; constructing a watchtower, guard house and pedestrian crossing for the use of park personnel; and initiating surveillance and sanitation projects with community participation.

Biological monitoring

Fish: A specific focus was to research Atlantic tarpon *(Megalops atlanticus)* to find out more about their population structure, the composition and diversity of communities at different sites, the correlation between environmental variables and their abundance, and to make recommendations on the feasibility of exploiting tarpon and other species for sport fishing. For comparison purposes, the study area was divided into 5 zones which differed according to the type of lagoon bed, depth, colour of water and associated vegetation.

We made three rounds of fish sampling in each of the five zones using a combination of fishing gear including cast nets, hand nets, hooks and harpoons, seines and other complementary gear. The type of fishing gear used

The five investigative zones of the Manatee Lagoon System Natural Protected Area

Fish monitoring and physicochemical parameters.

did not seem to impact on the species of fish caught.

Water samples were taken from each site on each sampling and tested for temperature, salinity, dissolved oxygen, pH, turbidity and transparency. The physical and chemical variables of the water recorded at the sampling sites did not present significant variations between sites.

In all, six fish species were recorded in the samples taken: Mayan cichlid or Mexican mojarra *(Mayaheros urophthalmus),* Yucatan gambusia *(Gambusia yucatana),* Yucatan molly or giant sailfin molly *(Poecilia velifera),* Atlantic tarpon, tilapia *(Oreochromis sp.,)* and Yucatan flagfish, also known as snakeskin killifish *(Garmanella pulchra).* The first four species were the most abundant overall. Atlantic tarpon were the most abundant species in zone 2 and zone 4 (see photo).

Results are still being analysed but the diversity of fish species and size collected would suggest that the Manatee Lagoon Natural Protected Area serves as a breeding and spawning site for various species of fish including Atlantic tarpon, although populations of the latter were quite low (8% of captured fish). Most captured tarpons measured less than one metre in length, indicating they were juveniles.

Sábalos del Sistema Lagunar Manatí.

Swamp crocodiles *(C. moreletii)*

Although the Manatee Lagoon System region is one of Yucatan's few remaining relicts of wetlands and mangroves that are still in acceptable conservation conditions, it was only in 2021 that the Lagoon's swamp crocodile population and habitat was monitored for the first time. We followed the National Monitoring Manual's methodology for habitat assessment of crocodiles and the National Night Visual Detection (DVN) methodology.

Crocodile

In this monitoring season we carried out two daytime censuses, in July and September 2021, during which we surveyed the size of the area, its forest cover, water hole and noted the presence of various fauna. We also carried out four night-time censuses, in July, September, October and November 2021, during which we observed a total of 92 crocodiles in 7 linear km of trail.

When averaged out for each site, sampling and the length of route taken, and taking into account that it is more difficult to observe crocodiles during rainy weather, this reflects a healthy crocodile encounter rate of an estimated 6 individuals per kilometre, which is above the national average of 3.3 individuals/linear km.

Most observed crocodiles measured between 0.70 to 1 metre in length, meaning these are juveniles or young adults. Ninety percent of them were observed in the coastal lagoon formations, with the remaining 10% observed in the swamp area of the 800 meters long communicating channel. These habitats appeared in good condition and appeared adequate for the crocodile's food and shelter needs.

The crocodiles were captured, examined, measured, marked, and released.

Construction of Manatee Lagoon Natural Protected Area infrastructure

This protected natural area needed control, surveillance and access infrastructure so that rangers, scientists, volunteers and other park personnel have somewhere to work, can regulate visitor access, and combat practices that threaten conservation.

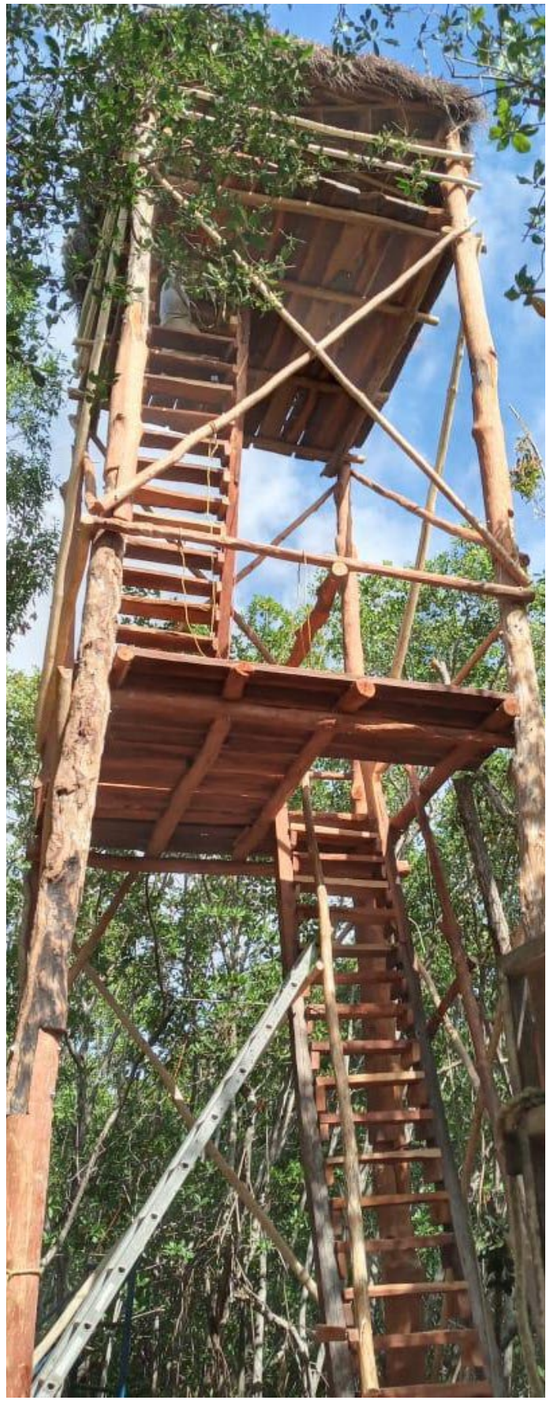
All the construction work was carried out manually and, where possible, using natural materials to minimise its environmental impact and preclude the use of heavy machinery. Prior to construction, all necessary urban and environmental permits were acquired from the competent authorities.

Watchtower

The completed 12-metre-high tower serves as a lookout to monitor for poachers, clandestine fishing, people illicitly dumping garbage, logging and other illegal activities. An 20 m2 area was cleared and a 9 m2 space marked out for the installation of the watchtower. The vertical uprights are 25-centimeter-diameter wooden posts dug into the ground to a depth of 2 meters and filled around with limestone and natural earth. The tower has two platforms accessed by stairways built from ¾-inch-thick planks and anchored with ½-inch bolts, and a thatched roof.

Guardhouse

Having received planning permission and with an architectural plan in hand, we removed rubble and solid waste from an area measuring 20 m² to create a space for building the guardhouse. We dug out and laid strip footing foundations, erected walls, cast beams, and installed the roof. All the work was carried out manually, with gravel and cement mixtures stored and prepared outside the reserve to prevent soil contamination. The guardhouse has a 18 m2 footprint and is currently being plastered and painted inside and out. It will soon be fitted with its rainwater collection system, biodigester drainage and electrical supply.



Watchtower

Pedestrian crossing

We built this mini bridge over a rainwater channel to allow safe pedestrian access to community members and operational personnel. The walkway measures 7 m long x 2.5 m wide and was constructed simply using hardwood load posts with beams anchored to reach over the water channel from bank to bank. Three quarter inch wooden flooring planks were secured with steel bolts, and an upper rail installed at a height of 1 meter.

Watch tower with thatched roof.

Community participation

We have been staunchly supported in our conservation efforts by the 10 members of the Chacmochuch River Participatory Surveillance Committee and the Manatee Lagoon Community who allocated 240 working hours to assist us in cleaning up and sanitising the Manatee Lagoon Natural Protected Area, as well as in monitoring wildlife, and training and sharing their experience and expertise with other community volunteers. An additional 10 people from Sanitary Jurisdiction 2 joined our activities to implement the Strategy for the Elimination and Modification of Breeding Grounds and Habitats of the Anopheles Mosquito (EMHCAS) Program to modify the habitat of mosquito-borne disease vectors. We spent 60% of our time desilting the waterways by removing 63 m³ of sludge and 5 tons of mud, and in collecting 5 tons of floating water lettuce macrophytes *(Eichhornia crassipes and Pistia stratiote)*. This exotic, invasive species reproduces rapidly and chokes the connecting waterways. We have come to realise that manual removal is a labour-intensive activity that gives only short-term results, so we are now researching a more cost-effective method to control it in the future.

We spent 48 hours clearing and removing 1,450 kg of garbage waste from the communicating waterways and within the mangroves. None of this waste could be recycled as it was all composed of old, dirty and deteriorated materials.
Another 48 hours were spent on surveillance tasks, monitoring expeditions and observations from the watchtower, as a result of which we filed two environmental complaints with the State Attorney for Environmental Protection and removed 2 loggers and four poachers along with their fishing gear from the park.
We also collected 1,450 kg of urban solid waste and special handling waste from garbage dumped within the protected area which is surrounded by the city of Cancun. Of the 25 garbage sites identified within the natural protected area in the first year of the project, we are proud to say we have eradicated 10, and have two more under control.

DEVELOPMENT OF PUBLIC POLICIES IN CONSERVATION AREAS OF QUINTANA ROO, 2019-2022

This collaborative project began in July 2019 and is supported by SAC-TUN and developed by the IBANQROO and Amigos de Sian Ka'an under the umbrella of the SEMA.

Creating two new protected natural areas in 2020-2021, work continued towards establishing two new protected areas (PAs) in Quintana Roo, which will expand the total area under conservation by 12,463 hectares. The two proposals for new PAs are for:

•The Bacalar Lagoon State Ecological Park to become the Bacalar Lagoon National Park that will include the Bacalar Lagoon within its boundaries and be increased in size to protect an additional 12,000 hectares of coastal wetlands.

•The Puerto Morelos Wetlands to be conserved as a state ecological park to protect the integrity of 463 hectares of medium-sized forests and wetlands that have been interrupted by roads running perpendicular to the coast that were built to provide access to coastal tourism developments.

The finalisation of supporting technical studies for these two new PAs scheduled for 2020-2021 was delayed somewhat by the COVID-19 pandemic which meant that some stakeholder consultation processes had to be postponed. Face to face workshops resumed in September 2021 with a workshop held at the Polytechnic University in Bacalar and attended by stakeholders from both civil society and government institutions.

We also continued working with the Quintana Roo University towards preparation of a justification study for the expansion of the Xcacel-Xcacelito Conservation Zone in Tulum. The study was presented to the protected area sub council with the proposal of extending it to join the Marine Turtle Sanctuary (about 1,000 hectares).

DEVELOPMENT OF A DRAFT COASTAL POLICY FOR THE STATE OF QUINTANA ROO[22]

In 2021, SAC-TUN, together with the German Cooperation Agency (GIZ) and Amigos de Sian Ka'an, supported SEMA's Quintana Roo Institute of Biodiversity and Natural Protected Areas (IBANQROO) and the CONANP in developing a comprehensive draft coastal policy for the state of Quintana Roo that will promote integrated management of the coastal zone through the application of various economic and socio-environmental instruments.

This is a new and exciting project for SAC-TUN which recognises that Quintana Roo's economy depends in large part on the environmental services provided by its iconic coast and rich marine natural resources, and the important role these play in sustainable development and livelihoods.

The draft documentation creating the first Coastal Policy for the State of Quintana Roo is also the first of its kind for any Mexican state.
The draft policy recognises the intricate interconnections between the state's inhabitants, geology, soil, cenotes, caverns, atmospheric water cycle, underground hydrological structure and the Caribbean Sea that create a high interdependence between nature and people.

Understanding this connectivity is the most important element for land-use and coastal policy since successful and sustainable urban and rural planning will have to consider this multitude of parameters, be adaptable to nature and be able to anticipate and provide solutions to challenges.

For example, over extraction of freshwater causes the aquifers to be impacted by saltwater intrusion. In addition, at least 80% of Quintana Roo's land mass is highly permeable which makes it vulnerable to contamination from agriculture, animal farming, urban run-off and other sources, all of which affect human and environmental health, as well as the biodiversity that sustains the ecosystem services which are the engine of economic development and livelihoods, supporting both. urban and rural populations and state tourism.

The adoption of a State Coastal Policy will foment sustainable coastal planning and management that will permit the people of Quintana Roo to maintain sustainable livelihoods, reduce the risk of flooding, minimise heat islands and saline intrusion into freshwater lenses, maintain a favourable permeable/impermeable land area, reduce pressure from rain in sewage drainage, reduce pollution from urban runoff to the ocean, increase adaptation to climate change, conserve corals, sea turtles, fish and pollinators, and maintain the spectacular freshwater lakes and ocean that attract numerous tourists to the state every year.

Inclusive and collaborative design of coastal governance strategies

The draft State Coastal Policy was led by SEMA and designed with the collaboration of more than 50 specialists from research institutions, civil society organizations and different departments of the state and federal governments who met in two participatory online workshops in 2021.

One workshop elaborated the strategic framework for drafting the State Coastal Policy, defining the parameters and data to be taken into consideration. The aim was to provide a detailed, factual snapshot of the current status of many of the interconnected factors that impinge on the coastal zone, including socio-environmental tendencies, conservation and proper use of natural resources and their connectivity, knowledge on best practices, valuation of environmental services and their incorporation into the system of economic instruments, demographics, characteristics of the local economy and data on economic growth, quality of life and social welfare, climate change threats and risks, the legal and institutional framework, economic and financial instruments, governance,

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

sustainable development and strategic planning needs, as well as chapters on the history, geography and environment of Quintana Roo.

The second workshop analysed this information to clarify the current state of coastal management in Quintana Roo and highlight successful areas and those areas that require more focus and attention if a balance between sustainable development and a thriving natural environment is to be achieved.

The draft State Coastal Policy recognises that Quintana Roo has been a pioneer in territorial planning with an emphasis on the environmental sector. However, lack of application of regulations, lack of intersectoral coordination, and the lack of an inclusive vision have meant that, on occasions, private and short-term interests have taken priority over common interests and long-term investments.

For example, a dynamic and booming tourism and construction sector has not been supported by the provision of basic housing, adequate urbanisation or good land use in areas with highly fragile ecosystems and natural resources. This short-sighted approach is reducing the possibilities of achieving the level of socio-environmental sustainability of cities and tourist destinations that could be the engine of development in Quintana Roo.

In addition, scientific and technical environmental and other data have not always been available to decision makers which has meant that opportunities have been lost to contribute elements of these to social and environmental sustainability.

The draft State Coastal Policy provides for a governance process based on seven underlying criteria:

1. Integration of policies, processes and programs towards a common vision of integrated coastal zone management.
2. Definition of short, medium and long-term strategies at a local level.
3. Synergy with the actions of civil society organizations.
4. Incorporation of available scientific and technological information.
5. Promotion of social and environmental research and monitoring actions.
6. Alignment to Mexico's National Policy of Seas and Coasts.
7. Coordination and concurrence of actions between the three levels of government

It describes three overall objectives:

Objective 1: *To contribute to improving the living conditions of the coastal populations of Quintana Roo through productive diversification and the sustainable use of natural resources in a comprehensive framework of development with equity, social participation and recognition of indigenous peoples.*

Proposed strategies to achieve this include economic diversification of the Quintana Roo coast, development of public spaces and promotion of sports activities in coastal towns, promotion of environmental education in schools, promotion of the culture of public goods among the coastal population, revaluation of indigenous knowledge and the promotion of alternative mechanisms for agri-food production, and taking actions to rehabilitate irregular human settlements and improve territorial and urban planning and coastal infrastructure projects.

Objective 2: *To strengthen the local economy through the promotion of the circular model, to improve regional competitiveness and contributions to the national economy, to promote institutional concurrence, agreement with other actors and to encourage responsible economic and productive activities with the marine and coastal environment.*

Proposed strategies to achieve this include promoting separation and recycling programs, developing an inventory of local, agricultural, forestry and artisanal products, promote the opening of green markets for local, regional and global marketing of products and services from the coastal zone, support local producers rather than buying foreign products, set up the required administrative institutions to improve integrated coastal governance and coordinated leadership, review, complement and adapt the legal-administrative framework to make this possible, generate mechanisms that permit coastal communities, civil society, businesses, local and regional academic institutions and others to facilitate and assist in government planning and transparency, and promote the blue economy and the economies of island communities.

Objective 3: *To value and maintain the ecosystem services of the coastal zone of Quintana Roo through innovation and the application of technical, legal and economic instruments for the conservation and restoration of biodiversity and its natural elements, promoting its resilience and regional and international cooperation.*

Strategies to achieve this include increasing the financial capacity for coastal development, drawing up protocols and programs for the monitoring, maintenance and restoration of coastal ecosystems, and developing policy and international agreements to promote sustainable coastal protection and development.

SAC-TUN has long recognised that synergy and collaboration in environmental and social projects are essential for successful outcomes and for a greater impact on sustainable development.

The draft Coastal Policy of the State of Quintana Roo recognises efforts made to date by the various national and international institutions, civil society organisations and private entities, including SAC-TUN, which have already made headway in developing various initiatives and projects to protect the environment and boost development in Quintana Roo.

The draft State Coastal Policy also includes tables of specific goals towards achieving each objective and strategy, including a time scale and specific outputs. This robust and broad draft vision for a State Coastal Policy, once adopted, will establish an important basis for the development of specialized instruments for the management of Quintana Roo's coastal resources.

What is the Blue Economy?

According to the World Bank, the blue economy is the "sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystems."

The European Commission defines it as: "All economic activities related to oceans, seas and coasts, covering a wide range of interlinked established and emerging sectors."

According to Conservation International, this includes: "economic benefits that may not be marketed, such as carbon storage, coastal protection, cultural values and biodiversity."

The State Coastal Policy will set Quintana Roo on track towards achieving 12 of the objectives of the 17 United Nations Sustainable Development Goals, namely:

Goal 1- An end to poverty

Goal 2- Zero hunger

Goal 3- Good health and well-being for all

Goal 4- Quality education

Goal 6- Clean water and sanitation

Goal 7- Affordable and clean energy

Goal 8- Decent work and economic growth

Goal 11- Sustainable cities and communities

Goal 12- Responsible consumption and production

Goal 13- Climate action

Goal 14- Life below water

Goal 15- Life on land

DEVELOPMENT OF MANAGEMENT PROGRAMS

Bacalar Lagoon State Park, Quintana Roo

The management program was completed and submitted to public consultation on the web pages of IBANQROO and SEMA. It is estimated it will be published in early 2022.

The management program was completed and submitted to the protected area sub council. It is being considered as a complex encompassing two protected areas (the Chachmochuch Lagoon System-Manatee Lagoon). The program was approved, submitted to public consultation and is awaiting publication.

SAC·TUN

PHOTOGRAPHY: SAC-TUN, AMIGOS DE SIAN KA' AN, COBI, ECOSUR, IBANQROO, PRONATURA, SEMA, SEQ.
SOME PHOTOS OF LANDSCAPES AND ANIMALS WERE COLLECTED FROM SHUTTERSTUCK*