Opwall Schools' Booklet

Mexico 2024

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1. Terrestrial project overview and research objectives

Meso-American Biological Corridor

Forest corridors are important for maintaining gene flow between animal populations and for ensuring that animal populations can withstand localized natural disasters such as droughts, forest fires, hurricanes and floods. Forest connectivity also ensures viable populations of animals with large home ranges such as spider monkeys, tapir and jaguar. Mexico's National Strategy on Climate Change (2007) called for establishing biological corridors between protected areas to "improve the adaptive capacities of ecosystems and species." One effort was the incorporation of five ecosystems in southeast Mexico into the Mesoamerican Biological Corridor Project, sponsored by the World Bank's Global Environment Facility. The corridors feature regions of high biodiversity, including dry and moist forests in Tehuantepec and Yucatan, cloud forests in Chiapas, savannas in Tabasco, and wetlands in Quintana Roo. These ecosystems are connected to one another and to the larger Mesoamerican Biological Corridor, spanning Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama. However, even within each ecosystem, forest connectivity is threatened by human population growth and urbanization.

Calakmul Biosphere Reserve

Forest corridors are important for maintaining. Calakmul is a large expanse of tropical forest that is continuous with the Maya Biosphere Reserve in the Petén Province of Northern Guatemala. Calakmul biosphere reserve covers an area of 723,000 hectares, but is attached to two state reserves Balam-kim and Balam-ku which run the entire length of the western side of the biosphere. The total area covered by these connected reserves is 1,200,000 hectares, but these reserves are surrounded by more forest giving rise to over 4 million hectares of forest. This Mexican forest is connected to the even more forest over the border in Guatemala, resulting in approximately 10.6 million hectares of continuous forest. Unlike the majority of forest in the Yucatan, the forest in Calakmul has not been used for timber production nor has it been burned for farming and ranching and as such, it is one of the last remaining stands of virgin forest in Mexico. The northern parts of Calakmul contains tropical deciduous forest, where trees typically have a canopy 8-20m high and lose their leaves in the dry season (December to May), but the majority of the reserve contains tropical semi-deciduous trees (Beletsky, 1999). Tropical semi-deciduous forest has a canopy ranging between 15-40m in height although the majority of trees are from 20-30m. The canopy can be closed or partially open and in the dry season, 20% to 40% of the trees lose their leaves (Beletsky, 1999). The dominant tree species in this forest are ramon (*Brosimium alicastrum*), chicozapote (*Manilkara zapota*), ceiba (*Ceiba pentandra*), zapotillo (*Pouteria reticulata*), chechen (*Metopium brownie*) chaca (*Bursera simaruba*), copal (Protium copal), tzalam (*Lysiloma bahamensis*) and caoba or mahogany (*Swietenia macrophylla*: Ogata et al., 1999). Calakmul also contains numerous temporary lakes known as aguadas, which form during the rainy season and may last well into the dry season. Wildlife in Calakmul includes jaguar, puma, ocelot, jaguarundi, tapir, brocket deer, peccary, howler and spider monkeys, in addition to over 50 species of reptile and amphibian and 350 species of resident birds.

This stretch of forest was also home to the two largest ancient Mayan cities of Tikal in Guatemala and Calakmul in Mexico during the pre-classic and classic period in ancient Mayan history (250BC-900AD). Today the extensive pyramids and ruined cities lie sprawled through the dense jungle, with some of the taller pyramids towering above the canopy at 65m in height. It is these payramids that gave Calakmul its name. "In Maya, 'ca' means 'two', 'lak' means 'adjacent', and 'mul' signifies any artificial mound, so 'Calakmul' is the 'City of the Two Adjacent Mounds'. This combination of Ancient Mayan ruins and outstanding diversity of wildlife is why Calakmul is an UNESCO Mixed World Heritage Site of Culture and Nature (UNESCO, 2015).

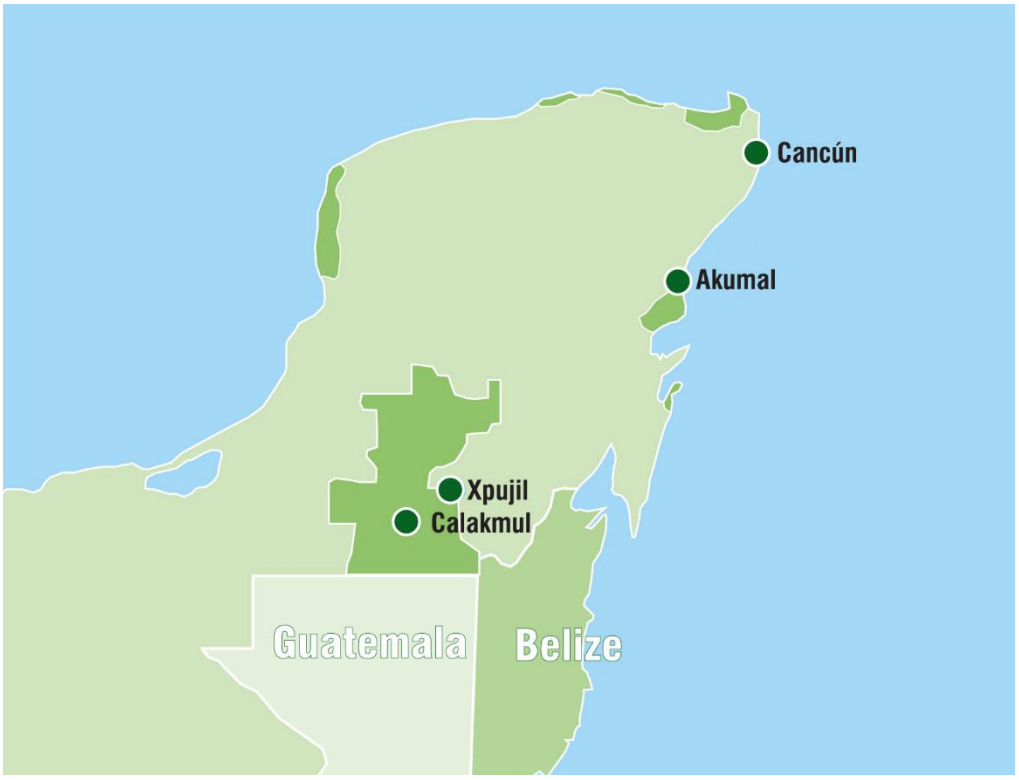

Figure 1. Map of The Yucatan Peninsula showing research locations

Today, over 20,000 people live in and around Calakmul in traditional Mayan villages where the traditional sources of income are slash and burn agriculture. Protecting the forest is therefore not just a case of creating a reserve, but educating and enabling local communities to utilise the forest resources in a sustainable manner. Buffer zone communities continue to grow in size and thus hunting of forest mammals is another major concern for the reserve. Some mammals (fast-producing species that live in high densities) may be hunted sustainably, but it is not possible to calculate sustainable hunting quotas for buffer zone communities until population density of mammals has been determined. The landscape has also been subjected to recent change due a reduction in rainfall and the loss of aguada habitats throughout the reserve.

Biodiversity Monitoring and Management of Protected Areas

The term "biosphere" was introduced by UNESCO to refer to a protected area larger than 10,000 hectares that contains one or more important biological zones, including significant pristine habitat and or wilderness areas that are untouched by people. The purpose of these reserves is three fold: to conserve biological diversity, to develop and serve as models of sustainable land use, and to provide areas for environmental research, monitoring, training, education and sustainable tourism. In order to determine the effectiveness of these protected areas at conserving biological diversity it is necessary to conduct annual biodiversity monitoring (Sutherland, 2006). Differences in the abundance and diversity of species across areas with varying degrees of human or natural disturbance can define the effect of changes to habitat on biodiversity and indicate areas in need of improved conservation efforts.

Permanent water bodies are rare in CBR due to the geologic characteristics that cause rapid filtration of the rain (García-Gil et al. 2002). However, low-lying terrain allows the accumulation of water, and creation of temporary lakes, locally known as aguadas. These aguadas are filled by direct rainfall combined with

water flowing across the forest floor during the peak of rainy season. As both water and leaf litter collect in these aguadas, the rotting leaf litter creates a mucus layer that stops the water filtering through the limestone karst. This system is entirely reliant on localized rainfall, and so changes to rainfall patterns can very quickly have a devastating effect on water distribution in the reserve. The prevalence of water in the aguadas of CBR has suffered alterations due to the effects of climate change (Reyna-Hurtado et al. 2010). For example, during the last 50 years Calakmul has endured a 16% reduction on the annual median precipitation values (Zuniga-Morales & Sima-Pantí 2015) followed by extreme fluctuations in the intensity and timing of rainfall over the last 10 years (Mardero et al., 2019). Changes to water availability in CBR have altered ranging patterns of ungulates such as peccary and tapir (Reyna-Hurtado et al., 2019) that are closely associated with water, which in turn is expected to affect ranging patterns of sympatric jaguar and puma.

Calakmul Research Aims and Objectives

Operation Wallacea is a UK based NGO that specializes in biodiversity assessment and monitoring of protected areas using the expertise of university academics and students. Although the Calakmul Biosphere Reserve is very well managed, the forest surrounding the reserve that connects Calakmul to the Mesoamerican Biological Corridor is disappearing at an alarming rate. The cause of the problem is increased population size combined with an unpredictable climate causing agriculture to fail. In conjunction with the reserve management team and our project partners Pronatura Peninsula de Yucatan we have developed ecotourism and sustainable agriculture projects with local Mayan communities in the buffer zone of the reserve. The data collected by students is being used to monitor the efficacy of these community projects in protecting the forest and its wildlife. The other major threat to the reserve is climate change and associated reduction in rainfall and loss of water sources, known locally as aguadas.

The aim of this project is therefore to assess the abundance, diversity and distribution of flora and fauna in the Calakmul Biosphere Reserve and monitor changes to this diversity over time in relation to changing water distribution and an increase in agriculture. The data produced from this project may then be used to assist with management decisions for the reserve, such as whether to intervene and mitigate aguada habitats.

These broad project aims can be broken down into a series of specific objectives as follows:

1. To investigate the abundance, diversity and geographical distribution of flora and fauna in Calakmul reserve, specifically that of trees, birds, bats, herpetofauna (reptiles and amphibians), and large mammals
2. To utilize survey data to understand the habitat preferences and ranging patterns of flagship species for the Selva Maya biological corridor such as jaguar, Baird's tapir and spider monkeys.
3. To utilize survey data to understand the relationship between forest disturbance and the abundance and diversity of herpetofauna
4. To utilize survey data to identify the most important forest characteristics for maintaining diversity of resident bird species
5. To utilize survey data to identify the relationship between forest disturbance and bat abundance and diversity
6. To investigate the relationship between forest structure and butterfly community assemblage
7. To utilise monitoring data to assess the impact of human disturbance (forest encroachment from agriculture and hunting) on the abundance and distribution of species in the reserve
8. To utilise monitoring data to assess the efficacy of sustainable development projects with buffer zone communities in maintaining forest coverage and diversity

9. To utilise monitoring data to assess the impact of the loss of aguada habitats on the abundance and ranging of fauna in the reserve
10. To create and manage a biodiversity database for Calakmul that may be used by all relevant parties to assist with management of the reserve

Calakmul can be divided into two separate sections, the original reserve under federal management (green area on Figure 2) and the new state reserves (brown area on Figure 2) that were added to avoid the bottle neck between the northern and southern sections of the original reserve. Data collection will be carried out in 4 different locations with the Calakmul Biosphere Reserve (Figure 2). These camp locations have been chosen due to their accessibility during the wet season and because they cover the full geographical and vegetation range of the reserve. Each camp will contain four 2km long transect lines for data collection. Each transect line will be mapped using a GPS unit. Five sample sites will be located along each transect line at 400m intervals, giving rise to 100 sample sites across the 4 research camps in the reserve. Each sample site will consist of a 20m x 20m area adjacent to the transect line. These sample sites will be marked and the GPS location recorded.

School groups will be based at one of two camps: KM19 or Hormiguero. Hormiguero is adjacent to a small ruins site of the same name and the camp is located next to a lake surrounded by forest. Transects are located in the forest close to the lake and within the ruins site. KM19 is located in the buffer zone at 19 km from the entrance of the reserve that is similarly surrounded by forest. Transects are located in the forest radiating out from camp. All data collection, lectures and jungle skills training sessions will take place in these camps. However, students will travel to the archaeological to complete the introduction to the Ancient Maya course where students will learn about the Ancient Mayan culture, social structure, architectural styles, gods, rituals and sacrifices and the specific uses of the different structures in the ruined city of Calakmul. This tour will provide amazing photo opportunities and some very entertaining viewing of the resident primates within the ruins site.

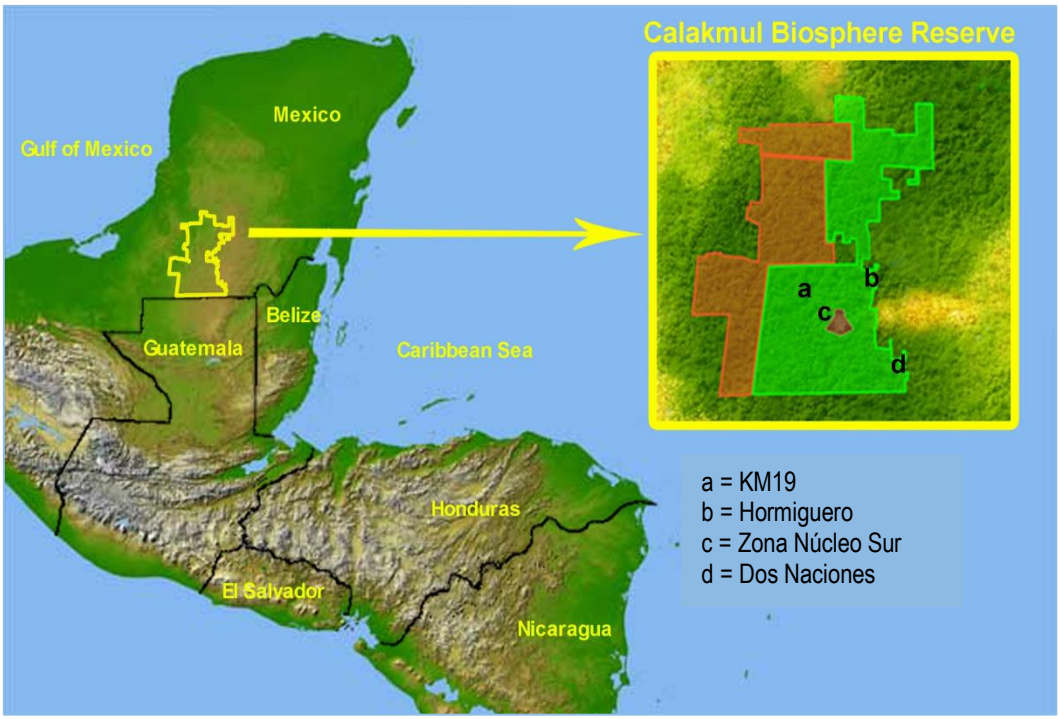

Figure 2: Study sites within the Calakmul Biosphere Reserve.

2. Week 1 Itinerary

The students on site will complete six days of training and research. These are divided into morning, afternoon and evening sessions. Students will arrive in the forest on Monday lunchtime and will attend a welcome lecture and briefings on health and safety, camp orientation and the schedule for the week for each group. The rest of the afternoon will be spent settling into camp and then students may join the nocturnal surveys after dinner. Student will then spend 4 days and nights receiving lectures, jungle training skills and assisting with data collection. Mid-way through the week, one afternoon or morning will be spent at the archaeological zone for the introduction to the Ancient Maya course. The project runs during rainy season so we expect all students to be flexible and understand why plans may need to be modified in the event of heavy rain. Accommodation at all these camps will be in tents.

During the briefings on the first day, students will be divided into small groups of 4-8 students. Students will stay in these small group when participating in biodiversity surveys (you see more animals if you enter the forest in small groups), but groups may join together again for lectures and meal times. An example weekly timetable is set out below (Table 1). Different groups of students will join different biodiversity surveys each day to ensure that all students get the chance to work with each of the different teams. The normal schedule will be a dawn start for the groups working with birds or mammals, around 8am for those working with herpetofauna or habitat and around 10am for those setting butterfly traps. These teams will then be back at camp mid to late morning with a bit of rest time before lunch. Straight after lunch there will be a lecture followed by afternoon data collection (birds, butterflies, mammals and habitat) or camp skills training that starts at around 4pm. The teams return to camp for dinner and after dinner some students (those who are not scheduled to start early the next day) will be scheduled to participate in nocturnal surveys for herpetofauna or bats. This schedule has been designed to avoid data collection in the heat of the day because physical activity at this time of day can be exhausting and because animal activity is extremely low at this time.

Table 1. shows an example timetable school groups during week 1. Note there may be changes to this schedule depending on size of groups, fitness of students, weather conditions or operational problems.

Day	Activities
Monday afternoon	Welcome lecture Health and safety briefings Camp orientation and allocation to small groups for survey work
Monday evening	Optional opportunistic surveys for herpetofauna or mist net surveys for bats
Tuesday morning	Large mammal transect surveys, bird mist surveys, habitat surveys, butterfly surveys or herpetofauna trapping and transect surveys
Tuesday afternoon	Lecture 1: Biodiversity monitoring in Calakmul Camera trap surveys, bird mist net surveys, butterfly surveys, habitat surveys or camp skills training
Tuesday evening	Herpetofauna transect or aguada surveys or bat mist net surveys (unless scheduled for early morning activities the next day)
Wednesday morning	Large mammal transect surveys, bird mist surveys, habitat surveys, butterfly surveys or herpetofauna trapping and transect surveys
Wednesday afternoon	Lecture 2: Forests of the Ancient Maya and their importance for primates Camera trap surveys, bird mist net surveys, butterfly surveys or habitat surveys

Wednesday evening	Herpetofauna transect or aguada surveys or bat mist net surveys (unless scheduled for early morning activities the next day)
Thursday morning	Lecture 3: Birds, bats and butterflies as indicators of ecosystem health Transfer to archaeological zone
Thursday afternoon	Packed lunch at the ruins Introduction to Ancient Maya:Guided tour of ruins
Thursday evening	Transfer back to camp Active searching for herpetofauna or bat surveys (for those that are not too exhausted!)
Friday morning	Large mammal transect surveys, bird mist surveys, habitat surveys, butterfly surveys or herpetofauna trapping and transect surveys
Friday afternoon	Lecture 4: Aguadas and herpetofauna Camera trap surveys, bird mist net surveys, butterfly surveys, habitat surveys or camp skills training
Friday evening	Herpetofauna transect or aguada surveys or bat mist net surveys (unless scheduled for early morning activities the next day)
Saturday morning	Large mammal transect surveys, bird mist surveys, habitat surveys, butterfly surveys or herpetofauna trapping and transect surveys
Saturday afternoon	Lecture 5: Felids and Ungulates Camera trap surveys, bird mist net surveys, butterfly surveys, habitat surveys or camp skills training
Saturday evening	Herpetofauna transect or aguada surveys or bat mist net surveys (unless scheduled for early morning activities the next day)
Sunday morning	Large mammal transect surveys, bird mist surveys, habitat surveys, butterfly surveys or herpetofauna trapping and transect surveys
Sunday afternoon	Lecture 6: Conservation Management Camera trap surveys, bird mist net surveys, butterfly surveys, habitat surveys or camp skills training
Sunday evening	Social evening
Monday morning	Travel to marine site

3. Camp skills

There will be briefings on camp orientation, how to identify and ameliorate risks throughout the Calakmul sites, jungle health and disease issues on your arrival day at Calakmul. In addition, there will be an afternoon session on camp skills that will be led by your camp manager. The session will teach you how to select a safe camp site (e.g. what characteristics of the forest to look for when selecting the camp location, where to locate toilets and washing facilities etc), how to make a camp fire, field cooking, water sterilisation, how to set up hammocks, mosquito nets and bashers etc. These may also include other skills such as basic first aid, how to deal with snake bites, navigation and where to find food and safe drinking water in the forest.

Learning outcomes:

- Awareness of dangerous plants and animals - from the briefings and demonstrations in the field
- Awareness of disease and health issues working in a tropical rainforest - from the medical briefings and additional information given by the accompanying medic
- Safe working practices in remote locations - this is to do with trekking procedures, keeping rehydrated and avoiding heatstroke, organising communication etc using information from the health and safety briefings and practical sessions
- Establishing a temporary field camp – students will learn what factors to consider when determining the location of a field camp, how to build the accommodation (e.g. slinging a hammock) and how to prepare food (building camp fires, cooking etc)
- Basic jungle survival – students will learn how to deal with emergency situations in the jungle and the application of skills such as basic first aid, navigation and finding food

4. Forest Structure Measurements

Assessment of habitat type and level of habitat degradation provides the backbone to biodiversity monitoring programmes and assessment of ecosystem health. Assessment of a range of habitat variables and monitoring of habitat changes over time can be used to interpret variation in space and time of faunal diversity and abundance. Modelling of habitat quality and animal distribution patterns can then be used to predict changes to the ecosystem caused by a range of management plans as a means of choosing the most effective method of land management for a given area.

Habitat surveys will be conducted in each of 20m x 20m survey sites to investigate tree diversity and forest structure. On each transect the first plot will be located at 200m, the second at 600, the third at 1000m, the fourth at 1400m and the fifth at 1800m along the transect line. The number of saplings (trees with circumference <15cm and a minimum height of 3 metres) will be counted for each plot. For each tree in the plot with a circumference >15cm, the circumference at breast height (which will be converted to DBH), whether the tree is alive or dead, and the tree species, will be recorded on datasheets. Where species cannot be identified in the field, photographs of leaves, fruit (if available leaves and bark will be taken for later identification from textbooks. If identification is not possible from photographs, then samples may be taken from the tree at a later date for full examination. CBH will be measured using 50m tape measures. The number of fallen trees and cut stumps in the plot will also be recorded.

Forest structure measurements include understorey vegetation, canopy cover and leaf litter depth. To measure understorey vegetation, the plot will be bisected to produce the four quadrants. A 3m pole marked in 0.5m segments will be used to record the number of vegetation touches on the pole in each 0.5m segment up to a maximum of 10 touches, every 1m along these bisecting tapes. If one of the positions coincides with a tree then each of the 0.5m segments will be recorded and having vegetation touches. The openness of the canopy will be measured by taking a reading with a canopy scope facing the largest opening in the canopy from the centre of each of the four quadrants and one from the centre of the overall 20m X 20m square. If any of these points is closer than 1m to a tree trunk, then the observation point should be moved slightly so that it is at least 1m from the nearest tree trunk. The perspex square has 25 dots engraved on the square. The observer should look upwards holding the square 20cm from the eye count the number of dots that coincide with gaps in the canopy to give a score out of 25. Leaf litter depth should also be recorded in each of the 4 quadrants and in the centre of the plot using a ruler to give 5 separate leaf litter measurements (mm) per plot.

5. Biodiversity Monitoring

Amphibians and Reptiles

Herpetofauna data will be collected using active searching along the forest transect lines between 9.30am-1pm (to monitor diurnal species) and between 7.30pm-11.30pm (to monitor nocturnal species). Searches will be conducted along the transect line and up to 2m either side of the transect line. The duration of the survey and total distance travelled will be recorded for each survey in order to calculate relative abundance of species that incorporates survey effort. For each animal observed the species will be identified using field guides (Lee, 2000; Kholer, 2008; Mandujuano et al., 2010; Cedeño-Vásquez et al., 2010), the GPS location and distance travelled along the transect will be recorded along with the time, weather conditions and habitat type. Wherever possible, the animal will be captured in order to mark for recapture (scale clipping of reptiles only) and to record additional information before releasing the animal in the same location as capture. For each animal captured the sex, age (adult or juvenile), weight (g), the length of the animal (SVL), length of the head, and length of tail (were relevant) and colouration (camouflage or aposematic) will be recorded. In addition, the animal will be photographed in situ (back, head and side).

Data collected in and around aguadas will involve two methods. Diurnal and nocturnal timed searches will be conducted for amphibians, snakes and lizards. For each capture, the sex, age (adult or juvenile), weight (g), the length of the animal (SVL), length of the head, and length of tail (were relevant) and colouration (camouflage or aposematic) will be recorded. In addition, the animal will be photographed in situ (back, head and side). Nocturnal crocodile count surveys will be conducted based on counts of eye shine reflected from torches. Each count will involve walking around the perimeter of the aguada searching for eyes with lights from torches. The process will be repeated several times until final numbers recorded become consistent across separate counts.

Birds

Bird data will be collected using point counts and mist netting. The point count surveys will be completed between 05:30am and 09:00am. If it is raining heavily or there are strong winds the survey should be cancelled. On all surveys the weather conditions at the time of the point count should be recorded. Point counts of birds (by sight or call) will be conducted at 10 different points along the transect a 200m intervals. No settling down period should be allowed with counts starting immediately. Then over the next 10 minutes for each species the following details should be recorded: species, number of individuals, whether the bird(s) was seen or heard, and the approximate distance of the bird from the observer (recorded at 5m intervals).

The abundance and diversity of understory birds will also be assessed using mist nets. Mist nets are unable to sample canopy and mid-canopy species adequately but does allow for quantitatively reliable data to be produced for tropical understory birds, allows for the identification of birds that are shy or seldom vocal, minimises observer bias, and produces results that are easily repeatable. Mist nets surveys will run 6 days per week at each research camp using a suitable existing clearing along one of the sample routes with enough space to erect two 12m long mist nets 2.5 meter high. The location of this mist net site will be marked, and the GPS location recorded. All mist netting will be conducted at the same site per camp. Mist netting with occur in the mornings between 6:30am and 10:30am (allowing time for bird point counts prior to mist netting) and in the afternoons between 3.30pm and 6:00pm.

The opening and closing time of the nets will be recorded each session and nets will be checked every 20 minutes for the duration of the survey. When birds are found in the net, the time of capture will be

noted. The birds will be taken out of the net, placed in a cotton bag for holding whilst other birds are being processed. As previous studies of avifauna in Calakmul have indicated that recapture rates are extremely low, a banding system using nail varnish of 10 different colours will be used to mark birds when captured. The birds will be weighed (to the nearest gm) and standard morphological measurements taken. The birds will be released close to the net site but far enough away to avoid them being immediately re-trapped. The abundance and community composition will be compared between habitats and all the species will be categorised into breeding, habitat and feeding guilds.

Bats

Bat mist nets surveys will run 6 nights per week at each research camp using a suitable existing clearing along the transects with enough space to erect five 6m long mist nets 2.5 meter high. Additional mist netting sites outside of the transects (e.g. adjacent to aguadas) may also be used. The location of each mist net site will be marked and the GPS location recorded. Mist netting with be conducted between 7:30pm and 1am, but as data collection may be affected by rain, the exact opening and closing time of the nets will be recorded each session. The nets will be checked every 15 to 20 minutes during the first 3 hours of sampling and every 30 minutes for the last three. All the bats will be extracted from the nets following standardized protocols so as to minimize the stress and will be kept in a capture bags for 30mins, maximum. This time will vary depending on the size of the bat and the sex; pregnant females will be measured and released. Bats will be weighed, sexed, and species, reproductive status, the length of the forearm, feet and leg will be measured.

Each bat captured must be marked to control for recaptures (i.e. capture-mark-recapture sampling). The marking of captures only needs to last for the duration of the study and as data collection will only be conducted over the summer so the same method of painting rings around the feet with different coloured nail polish can be used (where rings painted on the right foot depict mist net location and rings on the left foot indicate the number of times captured).

Butterflies

The relationship between forest structure and tree species composition with butterfly community structure will be investigated by placing a series of conical traps in different forest locations. Traps will be made from mosquito netting rolled into a large cylinder. Mosquito netting will also be used to enclose the top of the cylinder and a plastic plate will be hung from the bottom of the cylinder using wire. The plastic plate will be baited with rotten bananas and other fruit each morning at 10-11am and then checked in the afternoon between 3-4pm. Traps will be hung from suitable trees in different areas of the forest and a 20m x 20m habitat plot (using the previously described methods) will be conducted around each trap in order to record forest structure variables and tree species composition. A total of 10 traps (5 understorey and 5 canopy) will be used in each of the research camps. Each butterfly caught in the trap will be identified to species level and will then be released.

Primates and Large Terrestrial Mammals

Primates and large terrestrial mammals will be surveyed along line transects that were placed without any pre-determined knowledge of the distribution of the animals. Primates will be surveyed using distance sampling as they are conspicuous and the particular species present in the reserve do not shy away from observers. These data will be collected by walking the entire length of the transect line in small groups of 4-5 observers walking quietly and slowly (500-1,000 m/hr) starting at 6.30am, when the primates are most active and are easiest to detect. Each time a primate is encountered, the species, whether the animals was seen or heard, number of individuals (visual sightings only), perpendicular distance from the

individual to the transect line, habitat, time, distance travelled along the transect line and weather conditions will be recorded.

The distance sampling method is only suitable when animals are relatively easy to detect and is therefore unsuitable for monitoring elusive species or species that naturally live at low densities such as jaguar. Thus, an additional method will be used to monitor these species known as patch occupancy sampling. Patch occupancy sampling involves detecting animals based on tracks and faeces rather that visual or vocal sightings of the animals (Figure 3). These data will be collected at the same time as the primate surveys. For each track encountered the following data will be recorded: species, length and width of track, approximate age of track (days) and leaf litter depth.

In addition to transect surveys, large mammals are monitored using camera traps arranged in a trapping grid located in the core zone of the reserve away from the transect lines to avoid human disturbance. The cameras are left in situ from January through to the end of September each year (avoiding the peak of rainy season where excessive rain can destroy the cameras) and students will assist with the organization and analyses of photos using Time Lapse software loaded onto laptops in camp and changing of SD cards and camera batteries where necessary.

Figure 3: Jaguar and jaguar tracks seen during surveys at Calakmul

6. Biodiversity Lectures

Lecture 1: Biodiversity Monitoring in Calakmul

- Definitions of biodiversity
- Importance of biodiversity monitoring in protected areas
- Biodiversity monitoring, sampling strategies and replication
- How data is used for long-term monitoring
- Calakmul baseline data
- Calakmul monitoring data

Discussion/Activity – Discussion of the impact of climate change on aguadas and fauna in Calakmul what does our data suggest we should do?

Lecture 2: The Forests of the Maya and their importance for primates

- Formation of Central America and Great Faunal Interchange
- Climate, the Gulf Stream and ENSO effects

- Forest structure and tropical semi-deciduous forest
- Howler monkey diet and ecology
- Spider monkey diet and ecology
- Trees of Calakmul utilised by the Ancient Maya
- Impact of Ancient Mayan agro-forestry on forest around ruin sites
- Importance of ruin sites for primates in Calakmul

Discussion/Activity – What would the forest be like in Calakmul if it had not been manipulated by the Ancient Maya?

Lecture 3: Neotropical bats, birds, and butterflies as indicators of ecosystem health

- Bat diversity, diet and ecology in Calakmul
- Bats as indicators of forest disturbance and ecosystem health
- Importance of primary forest for bat roost sites
- Bird diversity, diet and ecology in Calakmul
- Birds as indicators of forest disturbance and ecosystem health
- Mayan agroforestry and bird diversity
- Frugivorous butterfly diversity in Calakmul
- Butterflies as forest indicators
- Understanding frugivorous butterfly distribution in Calakmul

Discussion/Activity – What other taxanomic groups could be monitored as indicators of ecosystem health?

Lecture 4: Aguadas and Herpetofauna

- Classification of herpetofauna
- Amphibians
- Reptiles
- Herpetofauna diversity in Calakmul
- Importance of aguadas for herpetofauna abundance and diversity
- Crocodiles and caiman
- Aguadas and endemic Morlette's crocodiles
- Colour adaptations in herpetofauna - camoflauge, aposmatism and mimicry
- Snake teeth and venom

Discussion/Activity – Adaptation quiz

Lecture 5: Felids & Ungulates

- Feeding ecology of forest ungulates
- Sustainable hunting of forest ungulates
- Baird's tapir conservation
- Disappearing aguadas and the impact on ungulates in Calakmul
- Felids of Calakmul
- Niche separation between sympatric jaguar and puma
- Activity budgets of felids and overlap with preferred prey

- Changes to felid and ungulate distribution in Calakmul in relation to aguadas
- Jaguar movements in Calakmul and the importance for wildlife crossings

Discussion/Activity – How would you approach Mayan communities to discuss sustainable hunting quotas?

Lecture 6: Conservation Management

- Conservation methods
- Endemism and importance for conservation
- Biodiversity hotspots
- Blue Planet Generation
- Opwall Conservation Model
- Conservation Management in Calakmul – Aguada Restoration
- Conservation Management in Calakmul – Sustainable Honey Production
- Conservation Management in Calakmul – Ecotourism

Discussion/Activity – Marketing strategies for Jaguar Honey

7. Learning Outcomes from Week 1

The students should achieve the following learning outcomes from the fieldwork, practicals, lectures and discussions/activities:

- Be able to define a rainforest and tropical semi-deciduous forest
- Be able to describe the key flora and fauna found in tropical Mexican forests
- Describe the Ancient Mayan Civilization of Calakmul
- Understand the importance of aguadas for sustaining wildlife in Calakmul.
- Describe survey techniques used to monitor bird, bat, butterfly, herpetofauna, primate, felid, and ungulate populations.
- Understand the impact of climate change on global weather patterns and the associated impact on the Yucatan Peninsula of Mexico
- Describe Ancient Mayan manipulation of the forests and how this impact on primates.
- Describe key differences in spider monkey and howler monkey diet and ecology.
- Give examples of the benefits and limitations of using birds, bats and butterflies and indicators of ecosystem health
- Describe the key feeding guilds for birds and bats in Calakmul.
- Describe the importance of aguada habitats herpetofauna diversity and for the conservation of the endemic Morlette's crocodile
- Give examples of cryptic, warning colourations, Batesian and Mullerian mimic species
- Describe how snakes are classified according to their teeth and venom
- Give examples of species that can be hunted sustainably and explain why
- Describe dietary niche separation between sympatric jaguar and puma
- Give examples of different conservation strategies
- Understand the importance of endemism for global biodiversity hotspots

8. Marine Project Overview

Sea Turtles, Seagrasses and Tourism

All sea turtles in the Caribbean are listed by the IUCN (2012) as endangered (green turtle, Chelonia mydas and loggerhead turtle, Caretta caretta) or critically endangered (hawksbill turtle, Eretmochelys imbricate, and leatherback turtle, Dermochelys coriacea). The diet and behaviour of green turtles (Chelonia mydas) are reported to change from the juvenile to adult life stages, with a more varied diet in adult turtles, whereas juveniles and sub-adults feed exclusively on sea grasses (Lopez-Mendilaharsu et al., 2005; Arthur et al., 2008). Large numbers of immature green turtles can aggregate around the same feeding ground and remain until the abundance of their preferred food sources have become depleted (Lopez-Mendilaharsu et al., 2005). A study of immature green turtle stomach contents indicated that over 80% of the diet consisted of sea-grasses with the majority being from the Thalassia genus (Mortimer, 1981).

As with all grazing animals, turtles show a strong preference for younger parts of the plants that have a higher nutritional content and are more easily digested due to the low lignin content (Bjorndal, 1980). Continuous grazing of turtles on the same sea grass patches maximises the nitrogen and protein content in the grass and decreases the lignin content by around 50% resulting in a nutritious and easily digestible food source (Bjorndal, 1980; Moran & Bjorndal, 2005). Turtle cropping of seagrasses substantially changes seagrass meadow structure (Lal et al., 2010 and feeding preferences for Thalassia results in changes to composition of seagrasses and macroalgae (Hearne et al., 2019; Martinez-Lopez et al., 2019). Intense grazing of Thalassia can eradicate entire meadows as turtles cause significant route damage to seagrasses. However, moderate turtle grazing of seagrasses can almost double leaf biomass production rates (Christianen et al., 2012) and, there is no evidence that turtle grazing has a negative impact on reproductive fitness of Thalassia (van Tussenbroek & Gonzales-Morales, 2017). Consequently, turtle grazing is an important part of the seagrass ecosystem.

Akumal research objectives

Akumal (meaning “home of the turtles”) is a small coastal town located approximately a 1.5-hour drive south from the major tourist destination of Cancun. Akumal Bay (Figure 1) is a key foraging area for immature green turtles due to the abundant sea grasses. The local population in the bay fluctuates, with as many as 80 individual turtles present at a time. Although sea turtles have always been present in Akumal, the resident population arrived relatively recently. Prior to 2005 there were no seagrasses in Akumal Bay, but in November of 2005, hurricane Wilma hit the coastline the waves essentially pulled most of the beach into the water, creating shallow water with a sandy bed; the perfect conditions for seagrasses to grow. By 2008 there was a growing population of green turtles in the bay and by 2010, snorkel tours with turtles because the primary tourist attraction in Akumal. With unregulated excessive numbers of tourist snorkelling in the bay, tourism began to take its toll on the turtles and seagrasses, but in 2017, Akumal was declared a marine protected area to ensure more sustainable management of tourism and the gradual recovery of the ecosystem.

The aim of this project is to investigate the abundance and distribution of immature green turtles in Akumal Bay in relation to the abundance and distribution of seagrasses *Thallassia testudinum, Syringodium filiforme* and *Halodule wrightii* and in relation to the distribution of tourists. The project will also investigate the intensity and distribution of turtle grazing on seagrasses. Snorkel tours with turtles have been restricted to a set route around the bay and the use of snorkel fins is prohibited in order to allow seagrasses chance to recover. However, it is still possible that turtle show high avoidance to tourists which would impact on the distribution of grazing across the bay. Consequently, the secondary aim of this project is to investigate turtle distribution patterns in relation to seagrass coverage and tourist

avoidance. If turtle avoidance of tourists is severe enough for them to avoid key grazing areas, then this information must be incorporated into the new management plan for the reserve.

The research area also provides the opportunity to study the recovery of coral reefs, but as natural coral recovery rates are so slow, we are assisting the monitoring of areas of reef restoration where coral fragments have been to artificial reefs composed of different substrates of varying structural complexity. Combined with mapping and monitoring of the existing reefs we are able to determine the positive impact of the new protected area on the coral reef ecosystem.

There are 4 bays in Akumal (Aventuras bay, Akumal bay, jade bay and Half Moon bay) and a lagoon called Yal Ku to the north of Half Moon bay (Figure 4). Our accommodation is located in a wooded lot on the other side of the 307 highway just a short 10-minute drive to the various beaches and lagoons used as survey sites.

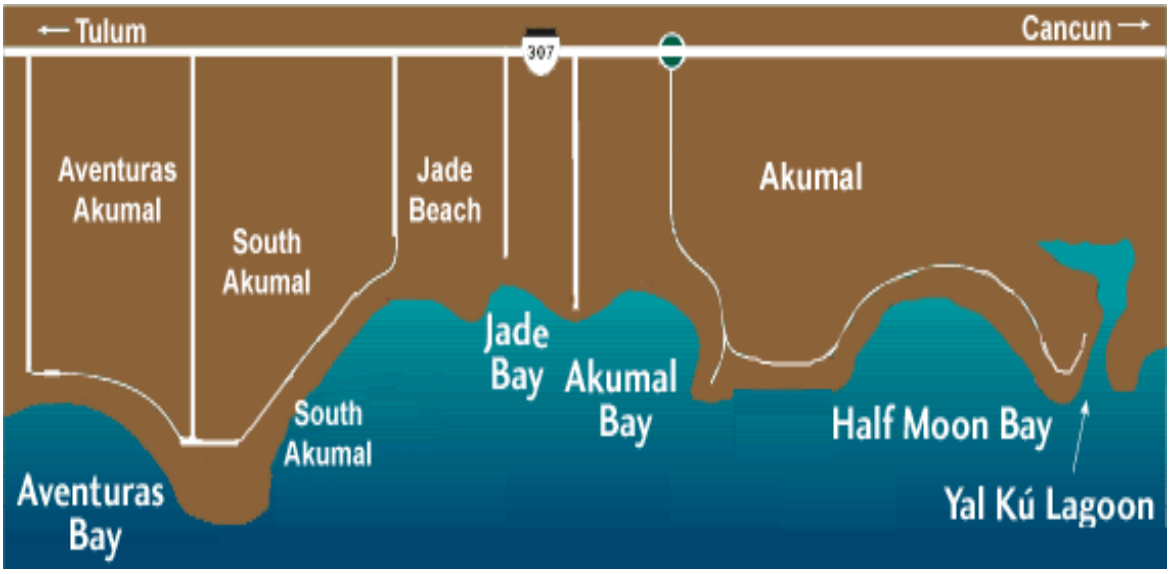

Figure 4: Map of Akumal showing location of the bays included in the Operation Wallacea monitoring programme

9. Week 2 Itinerary

The students will complete six days of training in marine science. Students will arrive at Akumal on the Monday afternoon and go directly to the research and accommodation facilities located in a beautiful wooded lot just a short 10-minute drive from the survey sites. Accommodation is in dorm rooms with fans and shared bathrooms. There are central dining and lectures areas on each floor of the three-story building. Students will eat breakfast at the accommodation site and then travel in minibuses to the designated bay for their diving and research activities. Students will spend the day at the survey sites and will eat lunch at these sites or back at the accommodation. While at the beaches there is a small selection of local restaurants and gift shops, supermarkets, and ATM machines.

If students are already dive trained or don't want to learn to dive, then they can take part in the Caribbean Reef Ecology Course (with the practical's done either by diving or snorkelling – see section 9). Alternatively, they can learn to dive to PADI Open Water level (see section 10). A third alternative is to complete their theory and confined water practical's before coming out and then just do their 4 open water dives to achieve the PADI Open Water qualification (see section 11) and then move onto the reef ecology course. Students will be occupied in the evenings through a series of science talks, documentary viewings and discussions/activities related to the Coral Reef Ecology course.

In addition to dive training and the reef ecology course, all students will have the chance to assist with day time turtle and sea grass monitoring between scheduled course activities.

11. Green Turtle and Seagrass Monitoring

Data will be collected on the seagrasses and resident green turtle (*Chelonia mydas*) population in Akumal Bay. Akumal Bay contains three different species of seagrass: *Thalassia testudinum* (Figures 2a and 2b) and fanerógama filiformes (*Syringodium filiforme* and *Hadolule wrigthii* Figure 3a and 3b). The area closest to the shore does not exceed 2 meters in depth, and is strongly affected by waves that stir up sediment and impair visibility. However, these waves are rarely large waves because the bay is protected by the coral reef. Areas closer to the reef have depths between 2-3 meters with better visibility as the waves are almost undetectable.

Figures 2a and 2b: *Thalassia testudinum* in Akumal Bay

The abundance and health of the seagrasses in Akumal Bay are monitored using a grid system of 150 survey quadrats, each $1m^2$, where the abundance of each of the three species of seagrass are recorded using the Braun-blanquet scale. The substrate on which the seagrasses are growing is recorded and the abundance of epiphytes growing on the seagrasses (an indicator of declining water quality) are also recorded using the Braun-blanquet scale. Students run through the key aspects of each species of seagrass during the seagrass and mangrove lecture and learn how to estimate coverage using the Braun-blanquet scale during the dry run of the seagrass surveys. Students will then locate their specific plot to survey using a GPS unit and collect the data on a dive slate while snorkelling under the supervision of our scientists.

11. Coral Reef Ecology Course

Table 2 below shows an example timetable of the activities that students undertaking the Caribbean Coral Reef Ecology Course will complete over the week. The contents of the timetable are comprehensive but the timing of the sessions will vary for each group. The practical element of the Coral Reef Ecology course can be completed by either diving or snorkelling. If students are already qualified divers by the time they arrive on site, they will be required to complete a compulsory check dive with a PADI Professional at the start of the course. The Coral Reef Ecology course is designed specifically for 6th Form students in mind. It covers a range of topics suitable to support A-Level biology and geography students over a range of different syllabuses. Lectures will be supported by in-water practicals. In addition to the lectures, a discussion/activity element will be sure to engage the students into the science and get them thinking themselves of the importance of the study topic.

The last day of the reef ecology course is where all students (even those who have been completing the PADI open water course) have the opportunity to assist with data collection and monitoring of the seagrasses. These data are used for our ongoing monitoring of ecosystem health in Akumal Bay.

Table 2 shows Indicative timetable for students completing the Caribbean Coral Reef Ecology Course. Note there may be changes to this itinerary depending on fitness of students, weather conditions or operational issues on site.

Day	**Schedule for reef ecology students**
Monday pm	Welcome lecture Dive documentation Allocation to groups for diving and practical sessions Presentation briefing
Monday evening	Lecture 1: Introduction to coral reefs
Tuesday am	Dive/snorkel practical - Check dive/skin diver course (snorkellers) First look at coral, invertebrate and fish ID plates Dive/snorkel practical – Fish sketching and buoyancy practice
Tuesday pm	Lecture 2: Underwater surveys – Theory and execution ID lecture – Algae and coral identification
Tuesday evening	Chasing coral documentary
Wednesday am	Dive/snorkel practical – Coral and algae identification Benthic transect dry run Dive/snorkel practical – Benthic transect survey
Wednesday pm	Analyses of benthic survey data Lecture 3 – Importance of coral reefs
Wednesday evening	Benthic quadrat survey briefing
Thursday am	Dive/snorkel practical – Benthic quadrat survey healthy reef Collate benthic quadrat survey results Dive/snorkel practical – Benthic quadrat survey degraded reef
Thursday pm	Comparison of benthic quadrat scores for both reef sites Lecture 4 – Turtles and seagrasses
Thursday evening	ID Lecture – Identification of coral reef fish
Friday am	Dive/snorkel practical – fish identification skills Fish abundance survey dry run Dive/snorkel practical – fish abundance transect survey
Friday pm	Fish survey data analyses Lecture 5 – Reef species and interactions
Friday evening	Lecture 6 – Reef threats and mitigation attempts
Saturday am	Dive/snorkel practical - fun dive/snorkel! Seagrass quadrat survey dry run
Saturday pm	Snorkel data collection – seagrass quadrat surveys
Saturday evening	Student presentations and Social Evening
Sunday am	Late wake up/packing
Sunday pm	Depart Akumal at noon

Lecture 1: Introduction to coral reefs

- Marine ecosystem representation in the media

- Introduction to hard and soft corals
- Coral anatomy
- Feeding
- Reproduction

Land-based activity: presentation briefing
In-water activities: check dive/snorkel, fish sketching and buoyancy practice

Lecture 2: Underwater surveys: Theory and execution

- What is marine monitoring?
- Considerations to be made
- The benthic environment (benthos)
    - Composition vs structural complexity
    - Why it needs surveying
    - How it can be surveyed
- The mid-water environment
    - Why they needs surveying
    - How they can be surveyed

Land-based activity: review of coral ID plates
In-water activity: coral ID

Lecture 3: The important of coral reefs

    - Biodiversity, productivity & its role as a nursery habitat
    - Fisheries
    - Coastal protection
    - Tourism & monetary value
- Coral reef distribution
    - Global distribution of coral reefs
    - The intermediate disturbance hypothesis

Land-based activities: Benthic survey dry run and data analysis
In-water activities: Benthic transect survey

Lecture 4: Turtles and seagrasses

- Seagrasses
- Sea Turtles
- Turtle grazing of seagrasses
- Seagrass and turtle monitoring in Akumal
- Seagrasses in Akumal Bay
- Seagrass coverage and health
- Impact of snorkel tours on stress related behaviour in turtles
- New management issues

Land-based activities: Benthic quadrat dry run and data analysis
In-water activities: Benthic transect surveys at healthy and degraded reefs

Lecture 5: Reef species and interactions

- Defining interaction types:
    - Competition
    - Predation
    - Symbioses (mutualism, commensalism & parasitism)

Land-based activities: Fish transect survey dry run and data analysis
In-water activities: Fish ID and fish abundance transect survey

Lecture 6: Reef threats and mitigation attempts

- Conditions for coral growth and survivorship
- Threats to coral reefs
- Ocean acidification
- Phase shifts
- Mangroves

Land-based activity: seagrass quadrat dry run
In-water activity:seagrass quadrat data collection

12. PADI Open Water Diver Course

This course consists of three different elements of learning; dive theory (knowledge development), confined water dives and open water dives. Each component plays its own role in the students' development to meet the performance requirements and objectives they need to become a qualified diver.

Please be aware that as a part of the PADI Open Water Course, all students will be required to complete some basic stamina tests on site. Student divers will need to demonstrate that they can comfortably maintain themselves in water too deep in which to stand by completing a 10-minute swim/float without using any swimming aids. Students will also have students complete a 200m continuous surface swim or a 300 m swim with mask, fins and snorkel.

Table 3 shows indicative timetable for students completing the PADI Open Water Course. Note there may be changes to this itinerary depending on progression through the course, fitness of students, weather conditions or operational issues on site.

Day	**Activity**
Monday pm	Arrive and settle in
Monday evening	Dive Documentation
Tuesday am	Dive theory
Tuesday pm	Evening science talk
Tuesday evening	Dive theory
Wednesday am	Confined water
Wednesday pm	Confined water
Wednesday evening	Dive theory

Thursday am	Confined water
Thursday pm	Open Water 1
Thursday evening	Dive theory
Friday am	Open water 2
Friday pm	Open water 3
Friday evening	Dive theory exam
Saturday am	Open water 4 & Dive certification
Saturday pm	Dive/snorkel practical 8 – fun dive! Seagrass quadrat surveys
Saturday evening	Social evening
Sunday am	Packing
Sunday pm	Depart Akumal

13. PADI Open Water Referral Course

For those students who have completed both the dive theory and confined water sessions prior to expedition they can complete their PADI Open Water Referral Course on site. The students will first complete a check dive with their instructor to demonstrate that they still remember and can confidently perform the necessary skills to progress on to complete their open water dives.
Once referral students have successfully completed the final stages of their PADI Open Water course, they will be able to progress on to the Coral Reef Ecology course. Although there will not be enough time to run the full course, referral students will be able to join at a stage where they can get the chance to learn about the application of survey techniques in the marine environment and how that supports the management of coral reefs.

14. Links to A levels and UCAS points

The following two tables highlight how your Opwall expedition relates to the AS and A-level syllabuses across all exam boards. The red blocks indicate that the keywords listed are covered on our expedition (through lectures, practical's or in discussion topics) and that these keywords are also within AS or A-level topics as shown.

Table 4: Highlighted in Black are topics that you might experience at your research site. Key: C = Cambridge. Pre-U, C.int = Camb. Int. CCEA = N.Ireland; Ed/Sal = Edexcel Salters, S= SQA ; Edex = EdExcel ; IB = International Bacc; AP=Advanced Placement (v. 20/11/14)

Topic	Biology	AQA		C	CCEA		C.Int		Ed/Sal		OCR		SQA		WJEC		AP	IB
	Levels: S=AS 2=A2 H =Highers	S	2		S	2	S	2	S	2	S	2	H	AH	S	2		
Evolution, Classification and DNA	Evolution; Speciation; Species; Endemism; Gene pool; Allopatric; Sympatric; Isolation; Variation; Adaptive radiation Adaptation; Wallace; Darwin																	
	Classification; Taxonomy; Binomial system; Dichotomous Keys																	
	PCR; Genome sequencing; Genetic fingerprinting; DNA profile																	
Ecology and Ecosystems	Ecology; Habitat; Niche; Abiotic; Biotic																	
	Biome; Ecosystems; Rainforests; Deserts; Coral reefs; Mangroves; Marine; Coasts; Hot arid; Semi-arid; Woodland Bush; Tropics; Tropical																	
	Populations; Competition; Interspecific; Intraspecific; Predator Prey; density dependent; independent: Symbiosis																	
	Succession; Climax community																	
	Biodiversity																	
	Practical work; Field techniques; Ecological sampling; Random sampling; Transects; Capture, mark, release and recapture; Biodiversity indexes; Data handling and; presentation; Quadrats; Statistical testing; Measuring; GIS; Research tools																	
	Written reports; Research project; Report; Case studies																	
Agriculture, Human activities, Conservation and Sustainability	Sustainability																	
	Agriculture; Agricultural impact; Agricultural exploitation; Cultivation crops; Food production; Sustainable agriculture; Sustainability; Forestry; Timber; Deforestation; Fisheries; Over fishing; Deforestation; Human management; Human effects; Human activities																	
	Fair-Trade; Coffee; Rain Forest Alliance; Ecotourism; Tourism; Carbon trading; Greenhouse gas emission control (REDD)																	
	Indicator species; Pollution; Climate change; Global warming Carbon footprint; Fossil fuels																	
	International conservation; Endangered species; Invasive species; Biological control; Pests; CITES; Ethical, Local; Global																	
	National Parks; Wildlife reserves																	
	Environment; Environmental monitoring; Environmental impact; SSSI																	
Behaviour	Animal behaviour; Primate Social behaviour; Territory; Predator-prey interactions; Herbivores; Grazing																	

Table 5: Highlighted in Black are topics that you might experience at your research site. Key: IB ESS = Env Systems and Societies; APES = Advanced Placement Env. Science (v. 20/11/14)

Topic	Environmental Science APES and ESS	IB ESS	AP ES	UK Geography A Levels AQA, Edexcel, eduqas and OCR
Evolution, Classification and DNA	Evolution; Speciation; Species; Endemism; Gene pool; Allopatric; Sympatric; Isolation; Variation; Adaptive radiation Adaptation; Wallace; Darwin			There has been a complete revision of UK Geography A levels. Although our expeditions are possibly not going to be as relevant to Geographers as they are to Biologists there are a significant number of topics covered by the various examination boards in which matching occurs with reference to: • human impact on ecosystems • ecosystems in general • biodiversity • sustainability • fair trade • work of NGOs • deforestation • climate change • case studies linked to biomes such as rainforests. All exam boards expect experience of field investigation techniques, statistical use and data manipulation which are very relevant to their experiences whilst on location at their expedition site. Almost all boards now require an independent investigation by students which fits really well with the present IRPs although the topic chosen must relate to their exam syllabus so topics such as the REDD scheme are possible choices. Their IRPs are between 3,000 and 4,000 words and should take up 4 days minimum to achieve. AQA have defined primary data as "Primary data is defined as unmanipulated data, either collected in the field or a raw dataset" which will work well with past data sets and the research data they help to collect when on their expedition. Specific detailed exam board matching is available on request.
	Classification; Taxonomy; Binomial system; Dichotomous Keys			
	PCR; Genome sequencing; Genetic fingerprinting; DNA profile			
Ecology and Ecosystems	Ecology; Habitat; Niche; Abiotic; Biotic			
	Biome; Ecosystems; Rainforests; Deserts; Coral reefs; Mangroves; Marine; Coasts; Hot arid; Semi-arid; Woodland Bush; Tropics; Tropical			
	Populations; Competition; Interspecific; Intraspecific; Predator Prey; density dependent; independent: Symbiosis			
	Succession; Climax community			
	Biodiversity			
	Practical work; Field techniques; Ecological sampling; Random sampling; Transects; Capture, mark, release and recapture; Biodiversity indexes; Data handling and; presentation; Quadrats; Statistical testing; Measuring; GIS; Research tools			
	Written reports; Research project; Report; Case studies			
Agriculture, Human activities, Conservation and Sustainability	Sustainability			
	Agriculture; Agricultural impact; Agricultural exploitation; Cultivation crops; Food production; Sustainable agriculture; Sustainability; Forestry; Timber; Deforestation; Fisheries; Over fishing; Deforestation; Human management; Human effects; Human activities			
	Fair-Trade; Coffee; Rain Forest Alliance; Ecotourism; Tourism; Carbon trading; Greenhouse gas emission control (REDD)			
	Indicator species; Pollution; Climate change; Global warming Carbon footprint; Fossil fuels			
	International conservation; Endangered species; Invasive species; Biological control; Pests; CITES; Ethical, Local; Global			
	National Parks; Wildlife reserves			
	Environment; Environmental monitoring; Environmental impact; SSSI			
Behaviour	Animal behaviour; Primate Social behaviour; Territory; Herbivores; Grazing, Predator-prey interactions			

15. IRPs or Individual Research Projects

In the last few years an increasing number of students joining our research programmes take this opportunity to undertake IRPs. These research projects take many different forms, but what they all have in common is the need to pose and answer a research question. Examples of these include Extended Project Qualification (EPQ), Extended Essay (EE) for IB, as well as many different projects specific to various education systems worldwide.

We can support a selection of different topics for either essay-based research projects or data-led research projects that are tailored towards what the students will experience on site. It is a fantastic opportunity for a student to witness first-hand many of the aspects of their research question and, in many cases, they will have access to samples of past datasets for their project. Students may also have the opportunity to talk with the actual scientists involved which will give them a convincing 'slant' to the way in which they answer their research question.

For success with IRPs, careful planning is needed by the student and a lot of the work will be done prior to their expedition. They will need close guidance from their school supervisor, and the scientists in the field need to be briefed so that support can be provided where they can. If you or your students are interested in undertaking a research project with us, you should contact roger.poland@opwall.com.

For more information visit the Opwall website - https://www.opwall.com/schools/educational-benefits/independent-research-project/.

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Electronic media

Documentary BBC Planet Earth, Episode 8: Jungles
Documentary BBC Planet Earth, Episode 9: Freshwater
Documentary BBC Life of Mammals, Episode 8: Tree Dwellers

Research questions

A level keyword link	Research area	Research questions	Suggested reading list
Ecotourism; national park; conservation	Biodiversity and Man's impact on wildlife	**Can ecotourism provide a viable alternative**	**Academic paper:** Sound the stressor: how Hoatzins (Opisthocomus hoazin) react to ecotourist conversation - Daniel S. Karp and Terry L. Root - Biodiversity and Conservation, 2009, Volume 18, Number 14, Pages 3733-3742

		income for the Calakmul Bioshere Reserve?	http://www.springerlink.com/content/hu8g74217981p481/fulltext.html **Article -** Eco-tourism: A sustainable trade? James Mair - DEC 2006 - http://news.bbc.co.uk/1/hi/sci/tech/6179901.stm **Paper** - Andrews, Joann. 1994. Evaluation of ecoturism potential, in the areas in and around the Calakmul Biosphere Reserve. PPY.
human impact; rainforest; deforestation	Biodiversity and Man's impact on wildlife	**Has deforestation in Central America slowed?**	**Other -** Statistics - http://www.biodiversityhotspots.org/xp/hotspots/mesoamerica/Pages/biodiversity.aspx **Other (website) -** World deforestation rates and forest cover statistics, 2000-2005 Rhett A. Butler, mongabay.com November 16, 2005 http://news.mongabay.com/2005/1115-forests.html **Article -** Deforestation in Central America 2006 : http://www.biodiversityhotspots.org/xp/hotspots/mesoamerica/Pages/biodiversity.aspx **Academic paper -** De Fries R, Hansen A & Turner BL (2007) Land use change around protected areas: Management to balance human needs and ecological function. Ecological Applications 17: 1031-1038 **Book -** P. W. Richards, University of Wales, Bangor - The Tropical Rain Forest An Ecological Study 2nd Edition - 1996 ISBN: 9780521421942
Biodiversity; mesoamerica	Biodiversity and Mans impact on wildlife	**Why are there so many species in Central American forests?**	**Report -** Biodiversity hotspots http://www.biodiversityhotspots.org/xp/hotspots/mesoamerica/Pages/default.aspx **Article -** Habitat Loss and Extinction in the Hotspots of Biodiversity - Brooks, TM; Mittermeier, RA; Mittermeier, CG, et al, CONSERVATION BIOLOGY Volume: 16 Issue: 4 Pages: 909-923 Published: AUG 2002 - abstract can be found on - http://onlinelibrary.wiley.com/doi/10.1046/j.1523-1739.2002.00530.x/abstract **Article -** Biodiversity hotspots for conservation priorities - Norman Myers, Russell A. Mittermeier, Cristina G. Mittermeier, Gustavo A. B. da Fonseca & Jennifer Kent - Nature - Volume: 403 Pages 853- 858 Published FEB 2000 - available at http://biolambiental.posgrado.unam.mx/pdf/Myers2000.pdf
classification rainforest population	Forest mammals	**Describe the large mammal communities of the Calakmul Reserve.**	**Book -** Krebs C (2006) Mammals. In WJ Sutherland (Ed.) Ecological Census Techniques: A Handbook Cambridge: Cambridge University Press pp 351 369 **Book -** Fiona Reid (1998). A Field Guide to the Mammals of Central America and Southeast Mexico. **Academic paper -** Myton B. 1974. Utilization of space by Peromyscus leucopus and other small mammals. Ecology 55: 277 290. http://www.jstor.org/pss/1935216

population ;sampling ecology	Forest mammals	**How do you estimate animal populations in the Calakmul Reserve?**	**Paper –** The use of camera traps for estimating jaguar Panthera onca abundance and density using capture/recapture analysis Oryx (2004), 38: 148-154 http://journals.cambridge.org/action/displayAbstract;jsessionid=DF9F1C3656DEC4752B6730BD7FA4498A.tomcat1?fromPage=online&aid=220195 **Book** – Timber, Tourists and Temples: Conservation and Development in the Maya Primack, RB – Chapter 6 Calakmul - http://books.google.co.uk/books?hl=en&lr=&id=VfVEsm95ArYC&oi=fnd&pg=PA81&dq=estimating+animal+populations+in+rainforest+calakmul+reserve&ots=xeYypQgchi&sig=VDh2Oy-8SmiSWUfquemyqZeQixY#v=onepage&q&f=false
Classification ; rainforest; population ; primate behaviour	Forest mammals	**Describe the social structure of spider monkeys – e.g. *Ateles geoffroyi***	**Article –** Spider Monkeys – reference list at the bottom of the Wikipedia article - http://en.wikipedia.org/wiki/Geoffroy's_spider_monkey **Article** – BBC website http://www.bbc.co.uk/nature/wildfacts/factfiles/310.shtml **Article – The Primata website -** Black-handed spider monkey - http://www.theprimata.com/ateles_geoffroyi.html
conservation ; sampling; biodiversity	Birds and sampling	**Does mist netting adequately describe the bird fauna of the reserve?**	**Book -** Gibbons DW & Gregory RD (2006) Birds. In WJ Sutherland (Ed.) Ecological Census Techniques: A Handbook Cambridge: Cambridge University Press pp 308 350 **Other -** Definition http://en.wikipedia.org/wiki/Mist_net **Article -** Using two survey methods to determine a suburban bird population by C Hansrote and M Hansrote http://elibrary.unm.edu/sora/NABB/v016n04/p0114p0118.p **Academic paper -** Derlindati, J., Enrique and Caziani, M., Sandra. 2005. Using canopy and understory mist nets and point counts to study bird assemblages in Chaco forests. The Wilson Bulletin 117(1): 92 99. Abstract found at http://www.bioone.org/doi/abs/10.1676/03063?cookieSet=1&journalCode=wils.1 **Academic paper -** Whitman, A. A., Hagan, J. M. and Brokaw, N. V. L. 1997. A comparison of two bird survey techniques used in a subtropical forest. The Condor Vol. 99(4): p955 965. Abstract found at http://cat.inist.fr/?aModele=afficheN&cpsidt=2062566
conservation sampling; biodiversity; transect	Birds and sampling	**The advantages and disadvantage**	**Book -** Gibbons DW & Gregory RD (2006) Birds. In WJ Sutherland (Ed.) Ecological Census Techniques: A Handbook Cambridge: Cambridge University Press pp 308 350

		s of point and transect counting to describe bird communities ?	**Book -** Bibby CJ, Burgess ND, Hill DA, Mustoe, SH. (2002) Bird Census Techniques (Second edition). Academic press: London **Article -** Avian ecology field methods http://en.wikipedia.org/wiki/Avian_ecology_field_methods **Book -** Howell SNG, Webb S. (2005) A Guide to the Birds of Mexico and Northern Central America, Oxford: Oxford University Press
Classification ; biodiversity	Reptile and amphibian communities	**What are the main species groupings of amphibians and reptiles in Calakmul Reserve?**	**Article -** Central American Herpetofauna http://pubget.com/paper/pgtmp_jstor1441404?title=The%20Origins%20and%20History%20of%20the%20Central%20American%20Herpetofauna **Other** – Yucatan Wildlife - http://www.yucatanwildlife.com/places/calakmul.htm Article – List of Reptiles of Yucatan Peninsula - http://www.yucatanwildlife.com/species/reptiles.htm
Alien/invasive/ species ; conservation population ; biodiversity	Reptile and amphibian communities	**What are the impacts of Chytrid fungus on amphibian populations in Central America?**	**Article -** Holland J (2009) Vanishing amphibians. National Geographic April 2009, available online at http://ngm.nationalgeographic.com/2009/04/amphibian/holland text **Academic paper -** Puschendorf, R., Castaneda, F. and McCranie, J. R. 2006. Chytridiomycosis in Wild Frogs from Pico Bonito National Park, Honduras. Ecohealth Vol.3 (3): 178 181. http://www.springerlink.com/content/2470032p58368067/ **Electronic media -** Definition and sampling video http://www.amphibianark.org/chytrid.htm
Population; biodiversity	Reptile and amphibian communities	**How can you estimate the diversity and population levels of reptiles and amphibians?**	**Book -** Blomberg S & Shine R (2006) Reptiles. In WJ Sutherland (Ed.) Ecological Census Techniques: A Handbook Cambridge: Cambridge University Press pp 297 307 **Book -** Halliday T (2006) Amphibians. In WJ Sutherland (Ed.) Ecological Census Techniques: A Handbook Cambridge: Cambridge University Press pp 278 296 **Book -** Gent T and Gibson S (2003). Herpetofauna Workers Manual. JNCC, Peterborough. **Book -** Bennett D (1999). Expedition Field Techniques: Reptiles and Amphibians. Expedition Advisory Centre, Royal Geographical Society, London. - http://www.rgs.org/NR/rdonlyres/9E3CF152-C817-470C-AC0C-C8FE82A8CBAD/0/Reptilesupdated.pdf **Academic paper -** Which Method s Are Most Effective for Surveying Rain Forest Herpetofauna? http://www.jstor.org/pss/1565833

Climate change; REDD;	Forest conservation	**How is total carbon locked up in a forest calculated?**	**Other - website -** http://www.un-redd.org/ **Articles -** Mongabay news articles on Carbon credits - http://news.mongabay.com/news-index/carbon%20credits1.html Article – Forest carbon stores may be massively overestimated New Scientist September 2010 http://www.newscientist.com/article/dn19408-forest-carbon-stores-may-be-massively-overestimated.html
ecology niche; trophic level	Forest Conservation	**Why are fig trees so important for the forest fauna?**	**Book -** P. W. Richards, University of Wales, Bangor - The Tropical Rain Forest An Ecological Study 2nd Edition 1996 ISBN: 9780521421942 **Other - definition** - Ficus - http://en.wikipedia.org/wiki/Ficus **Other - website** - Figweb - http://www.figweb.org/Ficus/index.htm **Book -** Burrows, J and S - Figs of Southern & South-Central Africa - http://www.figweb.org/Ficus/Fig_book/Figs_of_Africa.htm
Conservation ; human impact	Forest Conservation	**What are the main threats to the Calakmul Biosphere Reserve?**	**Report -** Parks Watch – Calakmul Biospehere Reserve – Thgreats - http://www.parkswatch.org/parkprofile.php?l=eng&country=mex&park=ckbr&page=thr **Artuicle–** Calakmul Biosphere Reserve – Heart of the Maya Forest Rich with natural and Cultural Wonders - http://www.parksinperil.org/files/page_2_calakmul_biosphere_reserve.pdf **Article –** Calakmul Biosphere Reserve – The Nature Conservancy – Parks in Peril - http://www.parksinperil.org/wherewework/mexico/protectedarea/calakmul.html
Evolution	Rainforests	**Why do more species live in Rainforests than in other ecosystems?**	**Other –** Save the Rainforest - http://www.savetherainforest.org/savetherainforest_005.htm **Paper** - Novotny, V., Drozd, P., Miller, S. E., Kulfan, M., Janda, M., Basset, Y., & Weiblen, G. D. (2006). Why are there so many species of herbivorous insects in tropical rainforests? *Science*, *313*(5790), 1115-8. American Association for the Advancement of Science. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16840659 http://www.mendeley.com/research/why-are-there-so-many-species-of-herbviorous-insects-in-tropical-rainforests/ also see related research articles.

Conservation ; biodiversity	Conservation	**What would be achieved by implementing the Meso – American wildlife corridor?**	**Article -** The Mesoamerican Biological Corridor – What is it, why is it significant? http://www.ecoreserve.org/2010/07/08/the-mesoamerican-biological-corridor-what-is-it-why-is-it-significant/ **Report –** Mesoamerican Biological Corridor Project - http://www.cakex.org/case-studies/1586 **Other – website –** Mesoamerican Biological Corridor - http://www.biodiversidad.gob.mx/v_ingles/corridor/mesoamericanCor.html
Evolution, colonisation	Conservation	**How has the formation of the central American land bridge influenced current wildlife communities in Calakmul?**	**Paper -** Marshall, L. G. (July–August 1988). "Land Mammals and the Great American Interchange". *American Scientist* (Sigma Xi) **76** (4): 380–388. Retrieved 2009-06-06. http://eebweb.arizona.edu/Courses/Ecol485_585/Readings/Marshal_1988.pdf **Article -** The Great American Interchange – good references **http://en.wikipedia.org/wiki/Great_American_Interchange**
Conservation	Archaeology	**Describe Calakmul at the height of the Mayan empire**	**Article** – Exploring the Calakmul Biosphere Reserve - http://www.planeta.com/ecotravel/mexico/yucatan/calakmul.html **Article** – The Lowland Maya site of Calakmul http://anth507.tripod.com/ **Article** – Lots of useful references at the bottom of the article - http://en.wikipedia.org/wiki/Calakmul#History