

Takata Experience

Coastal Habitat Mapping

Mahahual, Q. Roo, Mexico

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Objectives

The current project was conducted during the months of May and June, 2017. It had the following objectives:

- Produce a vectorial layer dividing the coast of Mahahual in habitats, mainly reef, seagrass, lagoon and mangrove. This layer will be delivered as a Shapefile, useable in any GIS.
- Produce a bathymetric map as a raster dataset + *lignes de niveaux*
- Produce a map of the area presenting habitats, dive site used by Takata, bathymetry and reference points (hotels, roads, docks).

These objectives were to be achieved using free of charge data. Spatial resolution of the resulting layers therefore depends of available data.

Data source

- Landsat 8
 - o Scene ID: LC80190472017134LGN00
 - o Date: May 17, 2017
 - o Accessible at: EarthExplorer

This Landsat scene covers Mahahual coast and has a total of 11 spectral bands at different wavelengths (see Table 1). None of the bands show distinctive features at depths greater than 20 m.



Figure 1 : Second spectral band (blue) from the Landsat 8 image of the area surrounding Mahahual, displayed in shades of grey (*more than 50*)

Table 1: Details of the 11 spectral bands of the Landsat 8 satellite

| Band Number | Wavelength (μm) | Description | Resolution |
|-------------|------------------------------|---------------------------|------------|
| 1 | 0.433-0.453 | Coastal / Aerosol | 30 m |
| 2 | 0.450-0.515 | Blue | 30 m |
| 3 | 0.525-0.600 | Green | 30 m |
| 4 | 0.630-0.680 | Red | 30 m |
| 5 | 0.845-0.885 | Near Infrared | 30 m |
| 6 | 1.560-1.660 | Short Wavelength Infrared | 30 m |
| 7 | 2.100-2.300 | Short Wavelength Infrared | 30 m |
| 8 | 0.500-0.680 | Panchromatic | 15 m |
| 9 | 1.360-1.390 | Cirrus | 30 m |
| 10 | 10.6-11.2 | Long Wavelength Infrared | 100 m |
| 11 | 11.5-12.5 | Long Wavelength Infrared | 100 m |

- Google Earth, 2/7/2015
 - o Date: May 2, 2015
 - o Source: Data Sio, NOAA, U.S. Navy, NGA, GEBCO

Google Earth offer a good resolution (< 1m), true-colour image of the entire area. It offers better contrast and potential for habitat differentiation than the imagery available on ArcGIS online. Visibility is poor at depths greater than 20 m.

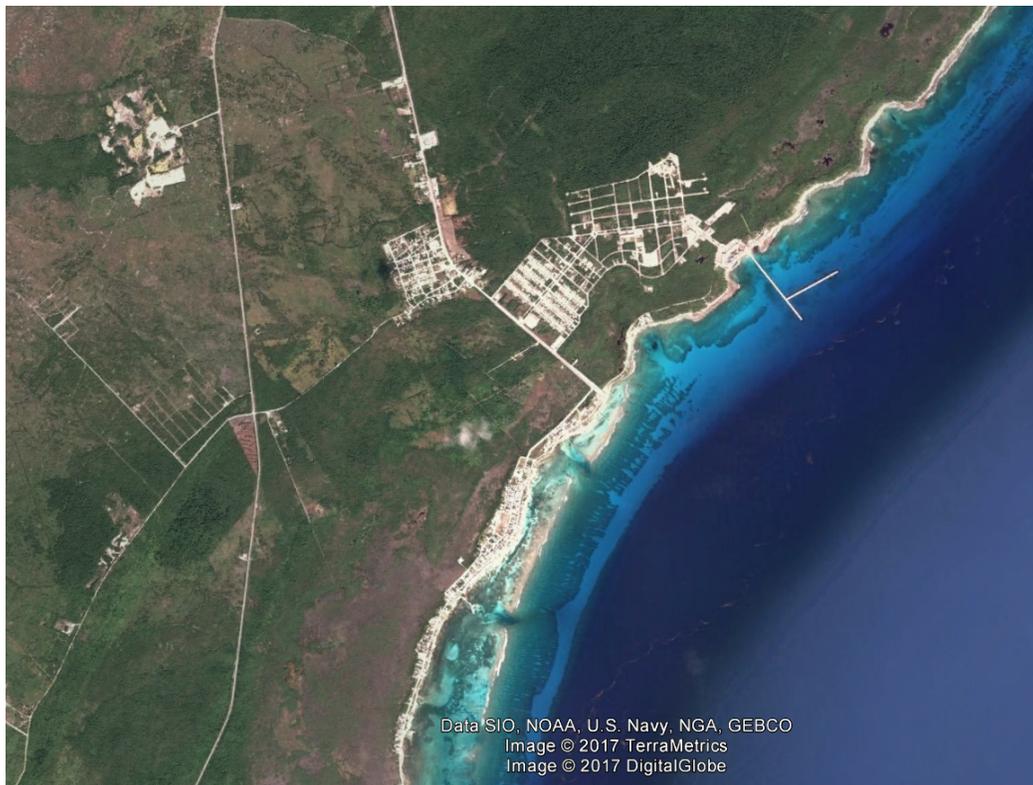


Figure 2: Satellite image of the area surrounding Mahahual, acquired using Google Earth.

Methodology

The spatial reference system used in this project is NAD_1983_2011_UTM_Zone_16N.

The first step of the project was to create some general reference layers to facilitate orientation. Simple imagery and base maps provided by ArcGIS were used to map the roads, main hotels and coastline of Mahahual, using feature creating tools. No attributes were added to the road layer, but hotel names were labeled. Takata Experience dive shop was also georeferenced as a reference.

Habitat mapping above 20m

Imagery used for habitat mapping was acquired by multiple screenshots of Google Earth at a scale of approximately 1 : 10,000. The screenshots were then georeferenced using 4 reference points with x and y coordinates calculated by Google Earth. The resulting rasters were merged to create an image of the coast of Mahahual, with a spatial resolution of *1.5 m*, where benthic characteristics can be observed in water of depth between *2 and 20 m*. Deeper waters appear a dark blue, from which no feature can be distinguished. In shallow waters, seagrass patches can be hard to delimit because of water turbidity.

The polygonal feature class "Habitat" was created, as well as a topology of the same name with the topologic rules "Must not have gaps" and "Must not overlap", to ensure the quality of the mapping of coastal habitats. Then simple visual polygonation was used to delimitate habitats visible on the Google Earth image. A field named "HAB_TYPE" was created in the attribute table, and habitat types were specified as either sand, seagrass, reef, emerged reef, mangrove, or anthropic. Area deeper than 20 m were marked as NA.

Habitat mapping below 20m

The main idea for mapping reef limits at depth higher than 20m is to have divers follow these delimitations and tracking their position using the GPS. Several tracking methods were considered:

1. The GPS is on the motorboat, and the captain aims to follow the SMB deployed by the divers

2. Divers are attached to a freediving float, and the GPS is secured inside the float
3. The GPS is on a smaller embarkation (e.g : kayak) which follows the SMB

The divers should stay at the minimum depth at which they can clearly see the limits of the reef. This should minimize their consumption and maximise their below water time, thus covering more distance in each dive. Days with good conditions (low wind and good visibility) should be prioritized, as waves will make it much harder for the embarkation to follow a straight path.

At the time of the exploration dives, weather conditions made it difficult for the boat to follow divers in a straight line. Moreover, poor visibility forced divers to stay deeper than would be optimal for their tracking. The buoy could not be kept exactly above the divers, but would instead be 5 to 15 m toward the shore, in a not constant way.

Even if these mapping methods did not provide satisfactory results, a few exploration dives were to visually assess reef limits in deeper water, as to confirmed habitat mapping on the edge of visible area of the Google Earth images.

Bathymetry

The method to estimate depth was adapted from Jagalingam *et al.*, in which are compared the observed radiance for the blue (band 2: 450 - 515 nm) and green (band 3: 525 - 605 nm) spectral band of Landsat 8 images. This is based on the fact that green light is absorbed by water at a faster rate than blue light. It is therefore possible to estimate the height of the water column, or depth, using a linear regression of the ratio of blue on green residual light detected by the satellite. Benthic composition should also be considered, as a sand covered seafloor will reflect light in a different way than a reef covered one.

The pixel values from Landsat 8 must first be converted in Top of Atmosphere (ToA) spectral radiance using the following equation:

$$L_{\lambda} = M_L Q_{cal} + A_L$$

where:

L_{λ} = TOA spectral radiance (Watts/(m² * srad * μm))

M_L = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number)

A_L = Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number)

Qcal = Quantized and calibrated standard product pixel values (DN)

According to the metadata published with the image:

$$M_2 = 1.2585E-02 \quad A_2 = -62.92700$$

$$M_3 = 1.1597E-02 \quad A_3 = -57.98669$$

For each pixel, the radiance value of the blue spectral band was divided by the green one to obtain what will now be called the blue-on-green radiance ratio.

The general equation developed by Jagalingam *et al.* to estimate depth is the following:

$$z = m_1 \frac{L_2}{L_3} + m_0$$

Where:

z = Depth (m)

$\frac{L_2}{L_3}$ = Blue-on-green radiance ratio

m_1 = Multiplicative tuning factor

m_0 = Additive tuning factor

Depth sampling is required to determine tuning factors. Sampling was done on a total of 3 dives following one transect each (Figure 3). Entry and exit point were registered on the GPS and a compass was used to ensure a straight trajectory. Depth was calculated every minute with a dive computer, and divers aimed to keep a constant speed. These dives provided a certain number of points for which verified depth can be compared to the radiance ratio.

Tuning factors were then determined for each type of marine habitat, using simple regression tools on Microsoft Excel.

Results et discussion

Habitats were mapped on 12 km along the coast of Mahahual (Figure 4). The area mapped had a width of 600 to 1500 m. The main obstacle to habitat mapping was depth: deeper than around 20m, no benthic features could be identified.

The first reef was easily and quite accurately delimited. The offshore limit of the second band of coral in front of Mahahual was at the limit of visibility. Its position was verified during exploration dives. Seagrass patches were harder to distinguish from the sandy area in shallow water. A few areas along the coast would have to be verified.

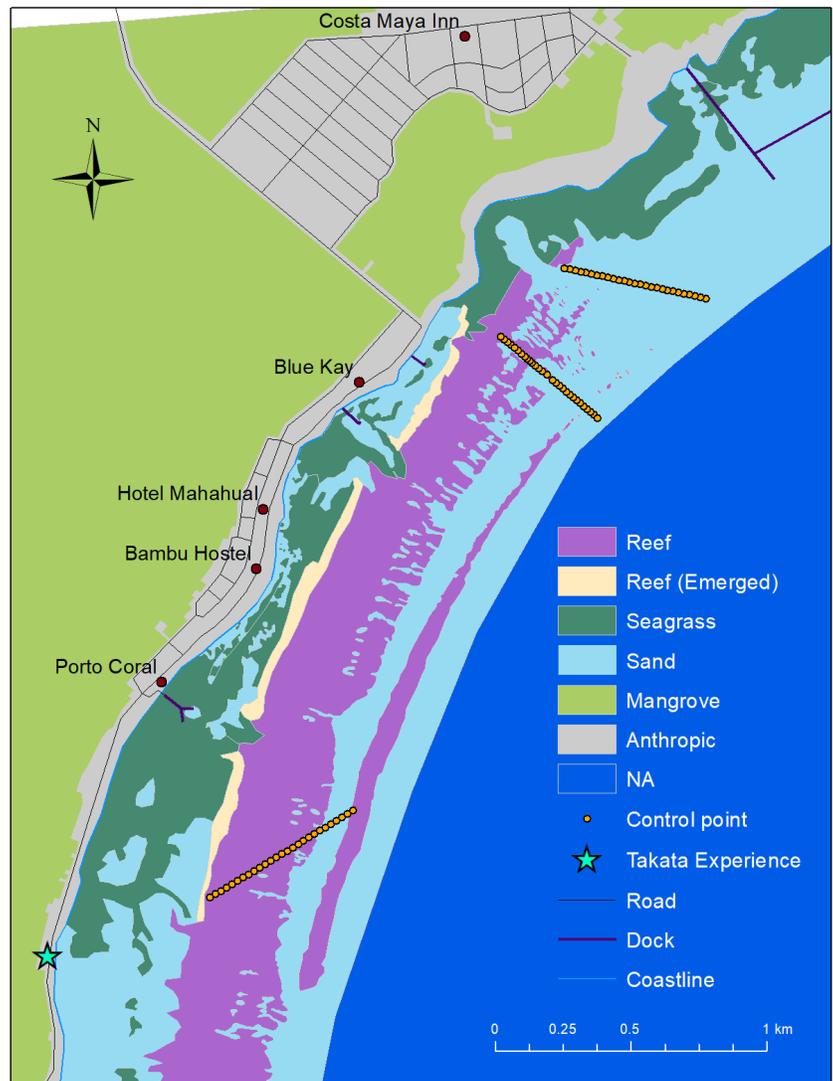
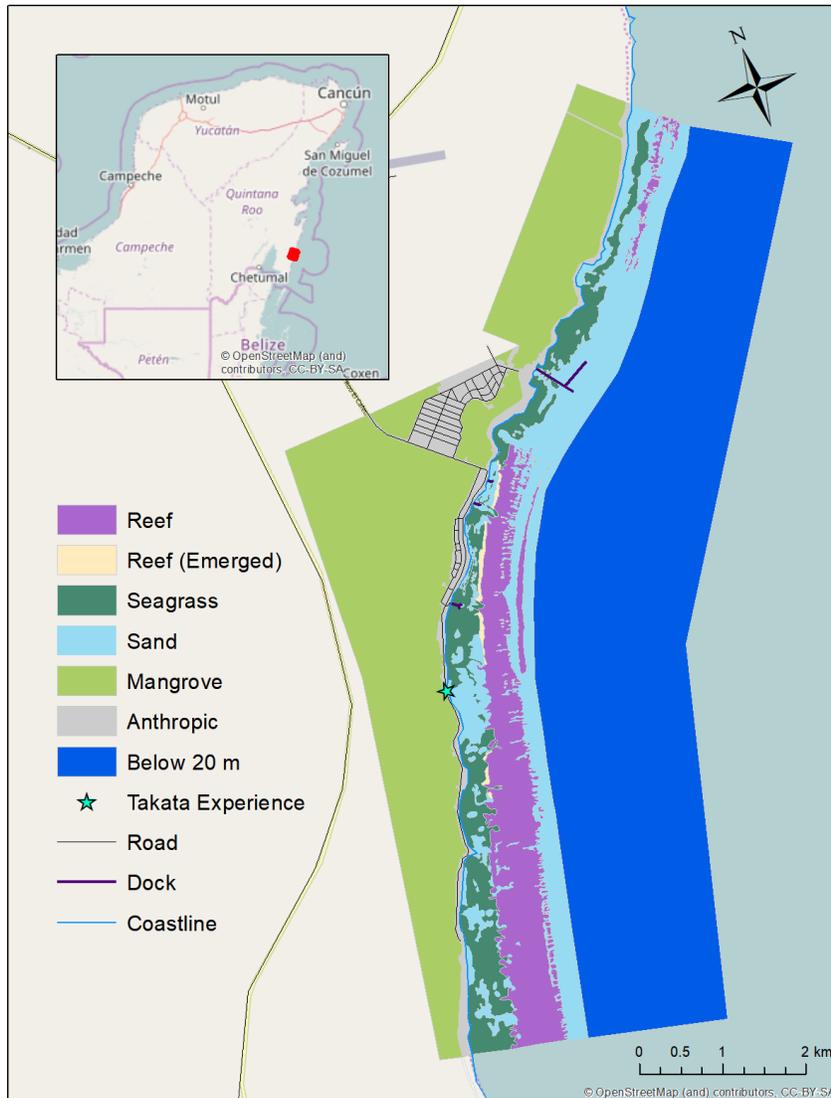


Figure 3: Position of transects sampled during the 3 experimental dives



This map offers a striking visual representation of anthropic impact on natural habitats. The 2 km gap in the coral reef coincide with the position of the cruise ship pier north of Mahahual. Inspection of historical satellite images seems to confirm that the reef was destroyed during the construction of the pier, but also that degradation of the habitat continued after its completion. One possible explanation is that the large amount of sediment uplifted by the passage of cruise ship could have buried corals living at proximity.

Figure 4 : Natural habitats from the coastal area surrounding Mahahual, Mexico, determined using photo interpretation

A total of 83 control points were sampled during 3 dives. The points taken on sand during the first dive (n = 7) were not included in the regression

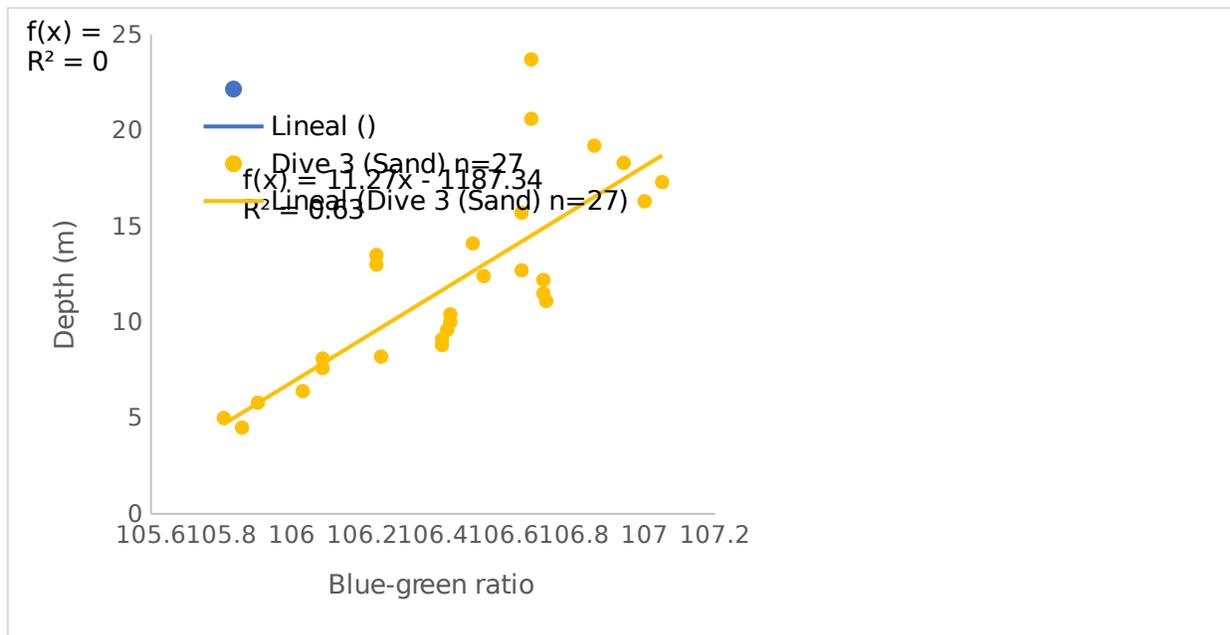


Figure 5: Relation between seafloor depth with the ratio of radiance for blue (450 - 515 nm) and green (525 - 600 nm) during three sampling dives on different substrate.

The relation between blue on green ratio of radiance with depth seems to differ according to benthic substrate. At same depths (5 - 15 m), sandy seafloor is associated to significantly higher radiance ratio than reef.

Data also seem to differ between dives, as points associated to the reef portion of the second sampling dive all have shallower depth than those of similar radiance ratio on the first dive. The same is roughly applicable when comparing the sandy portion of the second dive to the third dive.

Linear regressions were performed on the data from the first and third dive to obtain formulas to convert radiance ratio to depth (Figure 5). Coefficients of determination are decent, and these formulas could be applied to each pixel according to the habitat type associated to its extent. However, this process would generate a certain number of mixels (pixels covering the border between to habitats), for which we have no information on the relation between radiance ratio and depth. Moreover, we were not able to sample depth in seagrass area, neither did we gathered information on reef deeper than 14 m and sand shallower than 5 m, which habitats are present in significant amount in the study area.

Finally, the formulas published in this report are still associated to high margins of error: depths obtained with these formulas can differ from real depths by up to 8 m. Many more sampling dives should be completed to understand the real nature of the relation between blue on green radiance ratio, benthic composition and bathymetry. For now, blue on green radiance ratio (Figure 6) can serve as a relative reference for depths above 20 m.

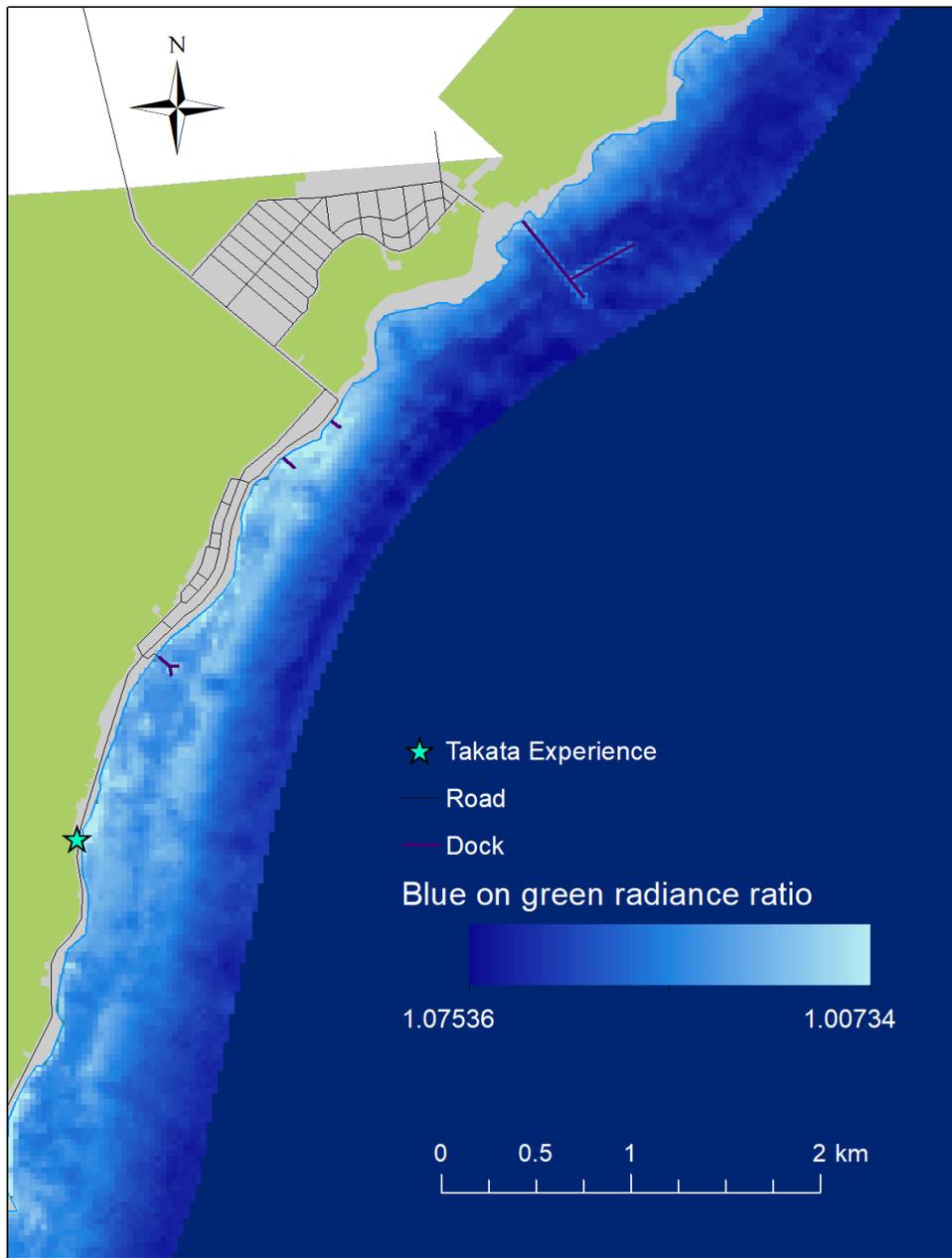


Figure 6: Blue on green radiance ratio of a coastal band surrounding Mahahual, Mexico, calculated using data acquired by Landsat 8.