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# Using Small Format Aerial Photographs (SFAP) to Map Coral Reefs in Rio Grande do Norte, Brazil

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**ABSTRACT**

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A heterogeneous range of remote sensor data is currently available to help mapping underwater entities. Particularly, data produced by orbital and sub-orbital sensors have been used with remarkable results. However, in some regions we need to associate accurate and cost effective methods to map over underwater features mainly in poor regions. This is exactly our proposal for the current work. The main goal is to produce maps of Maracajaú Coral Reef that can be used by researchers and managers to study and evaluate the actual conditions of the ecosystem considering its intensive use. We use vertical and oblique small format aerial photographs, taken from a small aircraft, to analyze natural and man-made entities. Analogical and digital methods are employed to analyze and interpret the images. It has identified emerged reef bodies, submerged reefs bodies, channels, sea grasses, rodoliths, carbonate sand areas, floatings and suspended sediments plumes.

**ADITIONAL INDEX WORDS:** *Coral reef mapping, Coastal mapping, Small format aerial photographs.*

## INTRODUCTION

Coral reefs are very important sea structures that give rise to an environment rich of life. Three main coral reef bodies appear in the inner continental shelf along the northeastern coast of Rio Grande do Norte (RN) State, in the North East of Brazil. We are currently investigating these bodies, which are located in a governmental, protected area, named "State Environmental Protection Area of Coral Reefs". We have mapped part of one of these bodies named by the local population as "Parracho de Maracajaú" (Figure 1).

This specific structure is located about 60 km to the North of Natal city in a wonderful sea region. It measures approximately 3 by 9 km, parallel to the coast, at about 6.5 km from the coastal line. The sea ground is basically composed by biogenic constructions and carbonated sand corresponding to a coral reef of the "frange" type. This is a shallow and clean water region, which is partially emerged at spring low tides (LIMA, 2002).

The region of "Parracho de Maracajaú" became an important tourist attraction in the last decade. Figure 2 shows the increasing number of snorkeling in just one of the 5 enterprises authorized to ecologically explore its body (Maracajaú Diver). The main reasons for this explosion in the amount of tourists are the favorable conditions of the water temperature, its transparence, and the shallow depth of the sea. Also, its huge biological diversity makes it a place highly used by both ecological tourists and fishermen. Figure 3 gives an idea of the types of occupation of the region under study. This is a reason why it is currently the priority area in a state project called Integrated Management of the Coastal Region (ORLA Project).

Despite supporting a large part of the local economy, the disorganized exploration of the tourist activities has produced a lot of damages to the coral reef ecosystem. It is very important to have all structures mapped in order to start researching and other activities giving support to government organisms in order to organize the correct development of the region.

When mapping coral reefs and associated underwater areas, a serie of techniques and tools can be used, ranging from autonomous diving to the use of remote sensing data. Remote sensing data is available in different forms, such as orbital satellite images and multi-spectral aero-transported sensors. The study of these areas using orbital remote sensors has been discussed in studies such as MUMBY and EDWARDS (2002) and ANDRÉ FOUËT *et al*. (2001), for example. This work presents a technique based on 35 mm digital photographs that were acquired and analyzed in order to map several structures in "Parracho de Maracajaú". Due to the film size and the used equipment, this type of data is generally known as Small Format Aerial Photos (SFAP). The main objective is to map the main morphological features, human activities, and to establish the physical limits of the region in a detailed way.

## PROPOSED MAPPING METHODOLOGY

In order to develop this project, a working rectangular area of about 2.0 x 1.5 km was selected. A picture including part of this area can be seen in Figure 4. It corresponds to the most used area in "Parracho de Maracajaú". Fishermen and tourists are the powerful users. We performed a detailed photo-interpretation in this area based on SFAP with verifications and checks

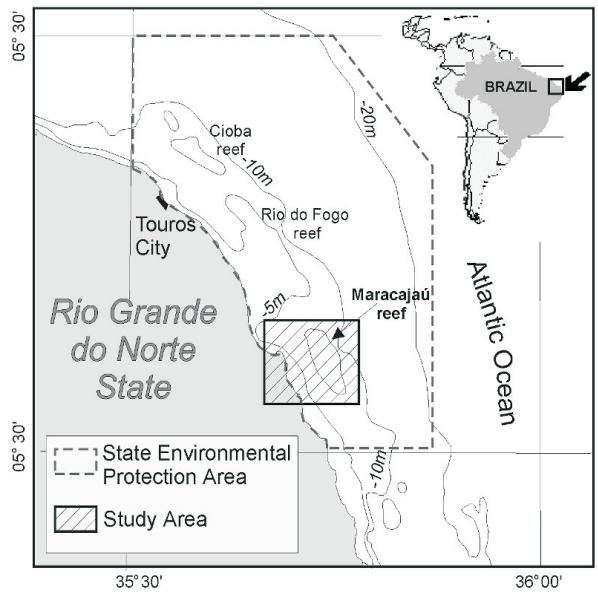


Figure 1. Map location of the area under study.

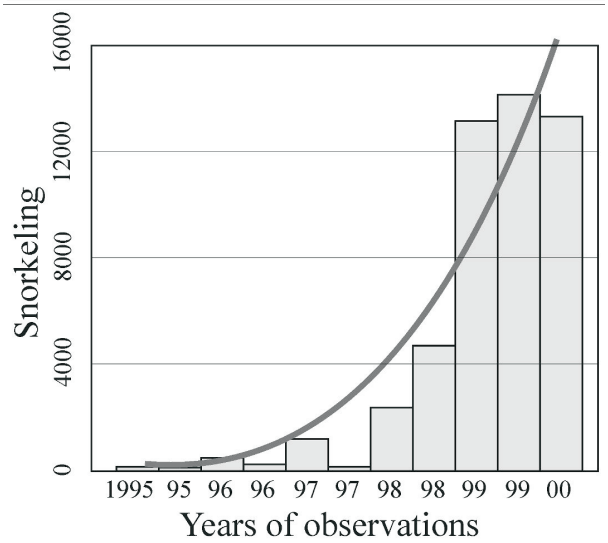


Figure 2. Snorkeling in Maracajaú coral reef from 1995 to 2000.

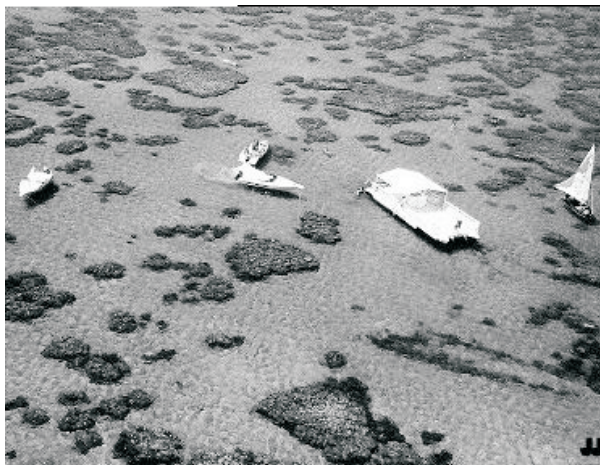

Figure 3. Oblique small format aerial photography of the area under study where we can see reef bodies in a sandy bottom and a touristtourist operation with launches and fixed floating. Photography taken by Jaeci Júnior.

performed in-loco to confirm the detected structures. The study of the environment using inexpensive, non-photogrammetric equipment and small aircraft has been discussed in studies as WARNER *et al.* (1996)

## Images Acquisition

A set of 35 mm aerial photographs was acquired along the selected area over the coral reef region on February, 8th 2001. A single motor airplane specially adapted for this task was used. This small aircraft was equipped with a SLR professional camera with polarizing filters. The photos were taken with the camera lens pointing approximately to the vertical direction. Photos were acquired by performing six flights in two series of three flights each of 3000 and 7000 feet height. This is approximately 900 and 2100 meters over the sea. Flight lines were obtained with approximately 60 % of forward overlapping and some 20% on lateral overlapping. We empirically experimented to start the acquiring process with time ranging from 10 to 11 am and during the spring low tide. A very clear day with few shadows in the sky was chosen in order to capture better underwater features. Color ISO 100 negative films were used. These films were developed and printed in 30x35 cm paper size. This resulted in photos with scales of approximately 1:5000 e 1:3000 for each of the above altitudes respectively. Also, films were digitized with a mean spatial resolution less than 1 meter. We noted that printed photos gave about 25 and 15 cm of resolution respectively.

## Enhancing Image Quality and Geo-referencing

Image quality was enhanced by using image processing techniques. A series of statistical treatments were applied in order to diminish water brightness on the images. Images contained in the above pilot area were selected and geo-referenced using as ground control points five vessels (or, as they are called in the region under study, "floatings"). The "floatings" can be seen as small white points in Figure 5A. One of them is shown in Figure 3 at a higher scale (the bigger vessel) in an oblique aerial photo. These floating boats are about 6 x 9 meters and are placed in a fixed location in the sea. They are currently used to support the tourist activities on the reef body. Floating positions were determined by using GPS (Global Positioning System) data, with differential positioning. Image enhancement and registration were performed by using a GIS software (we experimented with both ArcGIS and ERDAS). The floatings area was selected for a more detailed study using both visual interpretation and digital processing.

## Image Analysis

Digital and analogical treatments were applied in order to analyze the images. In the first method, the use of in-house computer programs based on digital image processing techniques and Geographic Information Systems were applied in order to allow analyze the images in a computer. Digital methods present the advantage of making possible the use of powerful computer l tools as image processing software, geographical information systems (GIS), interpolators, and others. These computer tools allow a series of complex analyses but also involve an inherent acquisition cost of the equipment. It also needs better efforts to prepare qualified people to operate the hardware and software tools.

In the second method, printed photos were put together by hand using overlapping regions as a basis to compose a photo mosaic for the traditional analogical study, also denominated overlay technique. When creating the mosaic, for example, some problems due to deformation can be minimized by performing an analogical and intuitive handling of the printed photos. However, the generation of a more accurate map, with a minimum of geometric deformation, is damaged. There are no current techniques available to deal with this problem. We are presently working on this issue.

# EXPERIMENTAL RESULTS

Figure 4 on the left shows a map of "Parracho de Maracajaú", obtained from a medium spatial resolution satellite image (Landsat 7). Underwater features detected in this image were: emerged reef bodies, submerged reefs bodies (or intertidal reefs), sand bottom, sea grasses, and a kind of bottom we could not identify.

Figure 4 on the right shows a higher scale map obtained by using the SFAPs methodology proposed in this work. The following underwater structures could be identified: emerged reef bodies, submerged reefs bodies, channels, sea grasses, rodoliths, and carbonate sand areas. After an *in-loco* verification we could see that these sand areas can be associated with shallow benthic (bottom) habitats. This could be confirmed as was suggested by previous work (CORAL REEF MAPPING IMPLEMENTATION PLAN, 1999). Although we can see the same natural entities in both maps, the geometry and mutual relationship are more clearly detailed in the SFAP map. On the other hand, the detailed mapping using SFAP makes it possible to see and monitor the type of uses of the coral reef. It is possible to detect, for example, floatings that are fixed vessels that implement tourist activities.

Figure 4. The map on the left shows the main features of the Maracajaú coral reef as interpreted by AMARAL (2002) using the

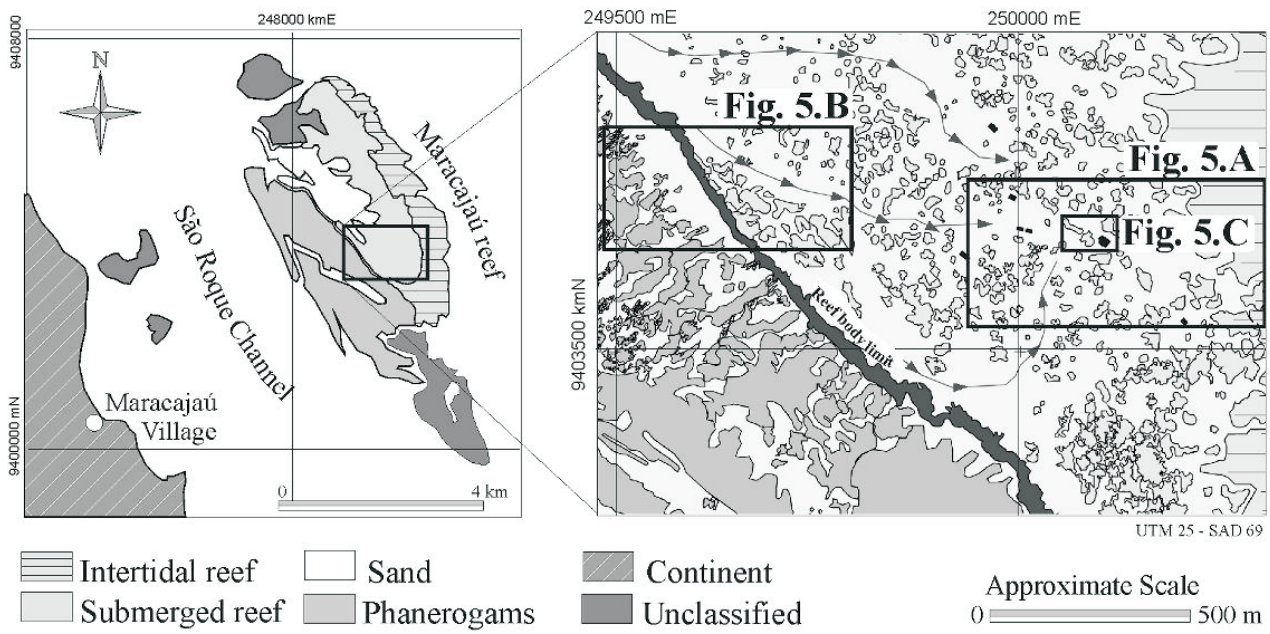


Figure 4. The map on the left shows the main features of the Maracajaú coral reef as interpreted by AMARAL (2002) using the Landsat 7/ETM sensor. The map on the right shows, in a higher scale, a rectangular area of this coral reef interpreted from SFAP. See in figure 5 examples of thoseat photographs in grayscale.

Landsat 7/ETM sensor. The map on the right shows, in a higher scale, a rectangular area of this coral reef interpreted from SFAP. See in figure 5 examples of those photographs in grayscale.

Figure 5 shows a serie of features that we can interpret visually by using SFAP in different scales of observation. With these kind of images, color is an important factor of interpretation but also with grayscale images it is possible to recognize the main features. We could recognize a sort of problems related to different types of uses. A plume of suspended sediments, for example, could be verified in images containing the boats. We found that this is probably due to the snorkeling activities from the vessels (Figure 5 A and C). The inner limit of the coral reef body is clear and it separates Phanerogams and coral bottoms (Figure 5B). Although the acquisition process had occurred near the spring low tide and on a clear day, it could be verified the presence of light on the objective (lens), even using polarizing filters. This problem reduced our data quality, particularly information about the sea ground surface. Acquisition time is then another important variable to be considered here.

## CONCLUSIONS

The use of SFAP to map underwater features in "Parracho de Maracajaú", supported by SFAP data and *in-loco* checking, has been done and the first results showed its efficiency and effectiveness. Of course, it must be considered as a complementary method and it must be done in association with other techniques. This is a cost-effective method that can be used to map the shallow water platform of Rio Grande do Norte and also of other similar regions with a high spatial and high temporal resolution. Thus, it is necessary to continue the mapping in order to encourage more specific researches on this ecosystem. The execution of this kind of research can establish the potentialities of the area, allowing the exploration with minimized environmental damages. Independently of the method used for analysis (by hand or by computer), the SFAP allows an accurate degree of details on determining the morphological features of the coral reefs body and also its limits. However, one of the most desired characteristics is that this methodology can be programmed with acquisition planned with a few days in advance. This is an important fact due to the constant presence of clouds over the region. This information, when complemented by the ones coming from other higher altitude sensors, can give rise to a well detailed panorama of the studied body.

Besides, previously mapping based on punctual data, channels and coral reef bodies, they could be also mapped in function of their geometries, that is, they are planes as observed in the SFAP photos. This procedure adds a series of new information which, if associated to working *in loco*, will make the analysis of the global behavior of the observed area easier. This allows, for example, the determination of other pilot areas for detailed studies. Features as underwater waved structures and sand fields were performed in previous tasks , which presented a more regional aspect.

This exploratory mapping of the "Baixo de Maracajaú", as it is also named, has also allowed the identification of types of uses as well as some environmental answers to this use. Besides having preliminary characteristics, results point out to new researches and actions to be carried out at short term. The detailed observation of the coral reef body allows the determination not only of its development pattern but also of the global spatial behavior of these characteristics.

Related to the individual analysis of these bodies, monitoring works should be done in order to evaluate the behavior of the geometry as well as the evolutionary behavior of the organisms such as sea plants, corals, and zoantides present in the body. The global observation of these bodies from SFAPs allows the determination of temporal changes in the spatial behavior of one or more selected areas due to the kind of use. In this way, it could be determined, for example, other "less destructives" routes for the boats that are used for transportation or recreation. Even relocating the floatings could be assessed based on the SFAPs.

Our next step is to organize acquired data and information, and to test them with other pilot areas. Also, a digital mosaic will be constructed of the whole coral reef body, allowing studies with higher resolution in a larger area. Our group is currently working on a project dealing with this topic. A series of submerged control points will be posted in the sea-ground, favored by the clean waters. Then pictures with a more accurate positioning will be acquired and processed. An aero-triangulation technique (as the photogrametry process of controlling data, popular to cartography, is called) will be implemented to get more precise control points. In order to better verify the resulting information, more checking in loco

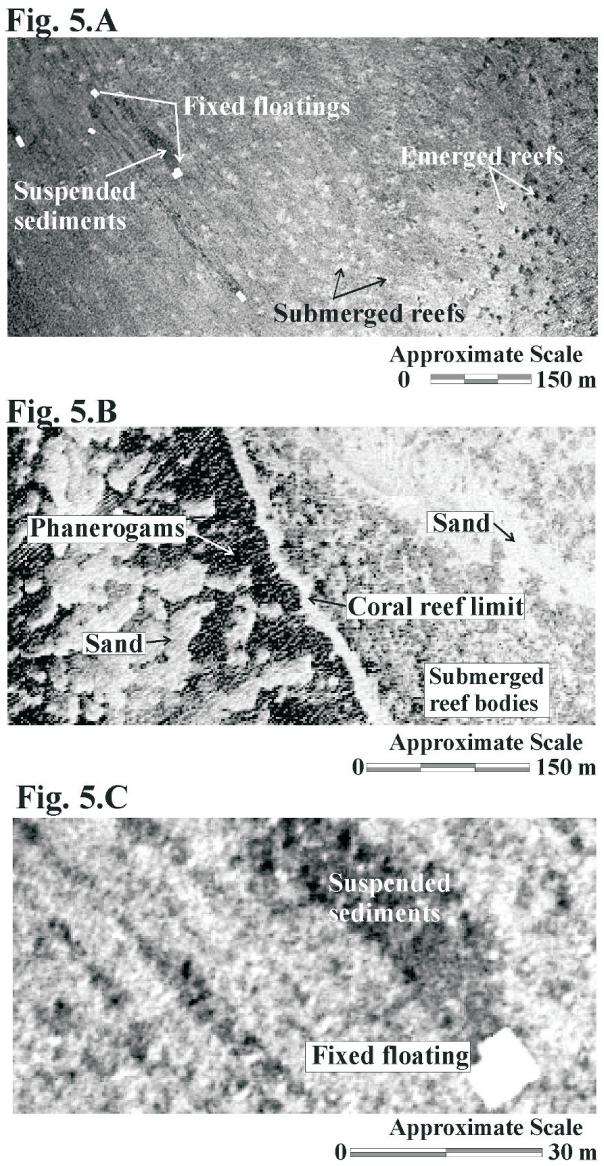


Figure 5. Detailed features detected observed from SFAP, in different scales. See in figure 4 the positions of these photos in a map of Maracajaú coral reef.

will be performed to complement it, also batimetric studies will be used and samples will be collected.

Finally, and as its main objective, this work has helped to protect the Maracajaú coral reef against destruction. This task is a continuous effort of the NEA (Center for Environmental Studies) group at Federal University of Rio Grande do Norte (NEA, 2003). Figure 6 shows a coral head found broken in "Parracho de Maracajaú", probably by a human subject while scuba diving or fishing, or either by a boat which passed over it.

## ACKNOWLEDGEMENT

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Figure 6. In the area where occurs intensive activities occur we can find lots of brokeneak coral reefs. To Ddistinguish differences among human made and natural damage is one of the goals of this study.

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