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Beach morphological changes in response to marine turtles nesting: a preliminary study of Awala-Yalimapo beach, French Guiana (South America)

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ABSTRACT

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Each year from February through July, *Chelonia mydas* (green turtles) and *Dermochelys coriacea* (leatherback turtles) come to nest on Awala-Yalimapo beach. During the nesting season, the presence of gravid turtles may directly affect the general morphology of the beach by provoking sand remobilization during firstly the conception of their nest and then during the nest disguising. Digital elevation models were realized to qualify and quantify the topographic modification conducted by the macro-bioturbation effect of marine turtles. Green turtles and leatherback turtles do not provoke the same perturbation on the beach. *C. mydas* affect the upper part of the beach by constructing their nest. Whereas *D.coriacea* provoke more important impact on the lower upper-beach when they come to lay. During the covering activity leatherback tend to disturb the morphology of the beach around their nests. Morphological changes on the beach during the nesting season draw attention to the potential effect of animal on their terrestrial habitat.

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ADDITIONAL INDEX WORDS: *Green turtles, leatherback turtles, macro-bioturbation, beach morphology*

INTRODUCTION

Along the Guianas coast, sandy beaches remain rare and unstable due to the highly fluctuating coastline resulting from the northwestward migration of huge mud banks originating from the Amazon river sediment discharge (Augustinus, 1978; Prost, 1989; Dolique and Anthony, 2005; Anthony *et al.,* 2010). The presence of these muddy sediments influences the coastal area by provoking alternate phases of mudbank and inter-bank. Therefore, sandy and muddy sediments are often mixed in the coastal environments (Dolique and Anthony, 2005; Anthony *et al.,* 2011). Sandy beaches are highly dynamic due to wave and tidal forcing. Beach dynamics normally result of natural processes which contribute to sediment supply or sink. Nevertheless, beach could be perturbed by either anthropogenic perturbation or animals.

French Guiana beaches represent an important nesting site for three species of marine turtles (Girondot and Fretey 1996; Fretey and Lescure, 1998). These three species are ranked by the IUCN red list as endangered for the Green turtle (*Chelonia mydas*) (Seminoff, 2004), critically endangered for the Leatherback turtle (*Dermochelys coriacea*) (Sarti Martinez, 2000) and the vulnerable Olive Ridley turtle (*Lepidochelys olivacea*) (Abreu-Grobois and Plotkin, 2008). Turtles come to nest on sandy beaches and thus require mud-free beach during the oviposition phases (Carr and Carr, 1972; Kelle *et al.*, 2007).

The shoreline dynamics engender shifting nesting site on the Guianas coast (Chevalier *et al.,* 2001; Gratiot *et al.*, 2006, Kelle *et al.,* 2007). Despite, the highly fluctuating coastline along the French Guiana coast, the beach of Yalimapo appears to remain sustain since 1950 (Péron *et al.,* in prep). As a consequence, this beach constitutes the most stable nesting habitat for marine turtles in French Guiana. Awala-Yalimapo beach hosts important nest of green turtles and up to 40% of the world population of leatherback turtles (Girondot and Fretey, 1996; Spotila *et al.,* 1996).

Marine turtles are organisms which spend almost all their life in the sea (estimated to 99%). Nevertheless, during the nesting season, these species come ashore and lay several clutches of eggs on sandy beaches. Sea turtles exhibit high-nest site fidelity (philopatry) to their natal beaches (Carr and Carr, 1972). The nesting behavior consists of a series of action and typical marine turtles nesting ethogram is (Hailman and Elowson, 1992; Miller, 1997):

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- Emerging from the sea
- Ascending the beach
- Finding the nesting site
- Digging a body pit
- Digging an egg chamber within the body pit
- Depositing the eggs
- Backfill the eggs chamber
- Covering activity by camouflaging the nest
- Descending the beach and returning to the sea

During the nest conception, a large amount of sandy sediments in this environment is remobilized and shifted all around the nesting site. These result in important bioturbation activities by marine turtles to cover their nest and to protect it against predators (Spotila, 2004).
Almost all studies had been devoted to the comprehension and description of the influence of the beach environment on the nest site distribution of the marine turtles.

Therefore this paper emphasize the potential effect of marine turtles on their nesting site by provoking changes on the beach topography.

STUDY SITE

The study was conducted on the 3km stretch of coastline of the estuarine beach of Yalimapo, situated in the western French Guiana (Figure 1), during the 2012 nesting season.

The beach is located on the protected site of the Amana nature reserve. According to Pujos *et al.* (2001) and from our observation, the western French Guiana is affected by heavy minerals such as staurolites, garnet and tourmaline. The coast experiences a semi-diurnal tidal cycle with a mesotidal range of a spring range of 4.1m and a neap range of 1m. Yalimapo beach presents a heterogeneous topography, thus, some parts of the beach is subject to strong beach scarp whereas other part present a gentle slope profile.

The vegetation on the backshore is composed mainly by *Ipomea pes-caprae* which is a pan-tropical plant that colonizes the coastal beaches from the upper boundary to the high tide line (Dewall & Thien, 2005; Conrad *et al.,* 2011).

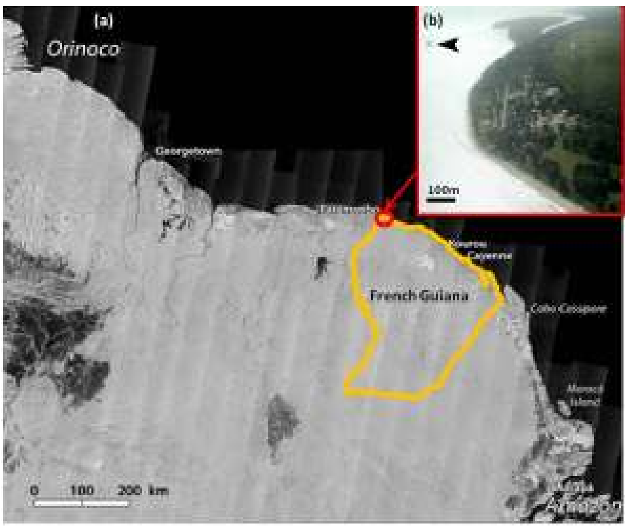

Figure 1: (a) Location of the study site (Red circle) along the Guianas coast (2006 JERS-1 satellite image); (b) Aerial photography of Awala-Yalimapo village and beach in 2011

MATERIAL AND METHODS

During the 2012 nesting season, each green (Figure 2A) and leatherback (Figure 2B) turtles nests position were located by a Garmin eTrex10 GPS and their location regarding the vegetation were noted each night from February to July 2012. In order to highlight the spatial distribution of green and leatherback turtles on the study site, the location of the chosen nesting sites by marine turtles has been classified in three different categories: the vegetation, the boundary between sand and vegetation (or scarp sometimes the boundary and the scarp location were merged) and the open sand.
High-temporal topographic measurements were realized in order to characterize the morphodynamics variation on Yalimapo beach. The topographic surveys were carried out by a LEICA 4700 total station and permit the realization of Digital Elevation Model (DEM). Topographic data were mapped by Surfer 7 Golden software. The data were projected in the WGS 84 UTM 22 North system. Instrumental errors are ± 3 mm for distance and height and ± 0.0015° for direction.
Between the 1st and the 6th of July, daily micro-scale topographic survey had been realized from the low tide line to the upper beach in the vegetation in order to cover all the possible perturbation within a study area. This period of neap-to-spring increases in tidal range allow to measure progressive tide effect on bioturbated beach.
During this experiment, about 300 topographic points has been measured daily. At the same time, the positions of daily high tide limits were located. In order to verify the hydrodynamic action on the sand mobilization, a perpendicular transect passing through the leatherback nest was extracted on the 1st to the 3rd July.
For the analysis of green turtles influence, a small study area on the beach from the digital elevation of the whole beach was extracted for a better appreciation of the potential disturbance. Therefore for the same area, around 45 points for the DEM of the 10th March and 290 points for the 18th May were measured. The number of topographic points differs for March and May survey as the number of topographic measurements is relating to the states of the landscape. Before the March survey, only a few turtles have already nested on the beach, and the beach displayed smoother appearance and the digital elevation model required less topographical points. While, the May topographical survey has been realized with a high number of points resulting of a highly rugged beach induced by an important concentration of turtles.

RESULTS AND DISCUSSION

Spatial distribution

During the 2012 season, we have counted 475 individuals of *C. mydas* which came to lay their eggs around 5times in the season, and a number of 365 *D. coriacea* which came to nest about 7 times during the season, resulting of about 4930 nests deposited on the beach. Due to the difference in green and leatherback turtles morphology, we could hypothesis that their nesting behavior induce variation on the beach. In fact, the body mass of a gravid green turtles averaged body mass is around 150kg (Figure 2A), whereas leatherback turtles largely exceeds 400kg (Figure 2B). The cross-shore location of marine turtles nests have varied according to the species (Figure 3).

The nest site selection plays an important role in the survivor of marine turtles eggs. The difference in habitat use ,from march to july, between the two species (table 1) is significant (chi-square=282,21, p-value<0.001). Several others study corroborate our results, therefore it has been observed that *C. mydas* preferred to nest near or within the vegetation (Whitmore and Dutton, 1985; Hays *et al.,* 1995) whereas *D. coriacea* preferred to nest on the open sand (Whitmore and Dutton, 1985; Kamel and Mrosovky, 2004) (Table 1).

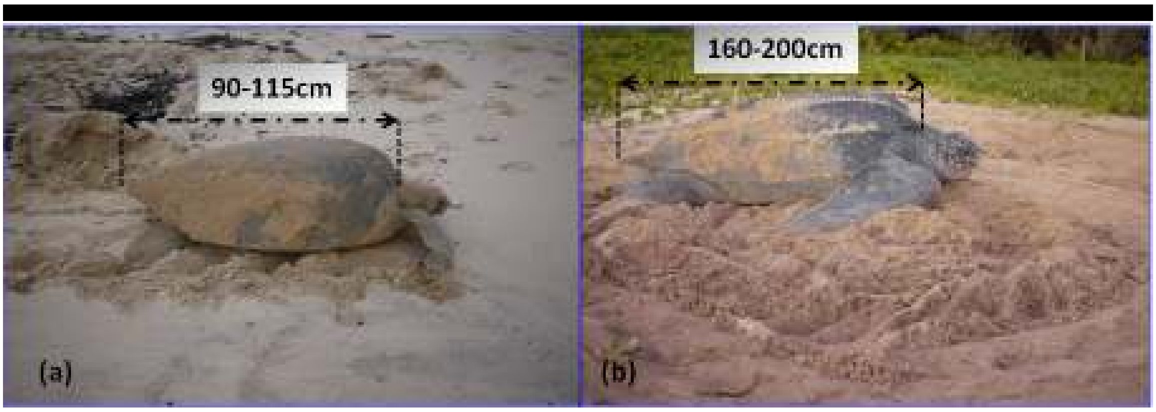

Figure 2: Green turtle (A) and leatherback turtles (B) (©Péron)

Table 1: The number of sightings of *Chelonia mydas(Cm)* and *Dermochelys coriacea (Dc)* nests (Column orange: period between march and may; column blue : period between may and july) are shown in the table, with percentages in parentheses.

	Cm		Dc	
Vegetation	332(41.7)	42(26.1)	23(6.2)	99(7.4)
Sand/vegetation	140(17.8)	18(11.5)	29(7.9)	431(17.5)
Open sand	327(40.5)	99(62.4)	311(85.9)	42(75.1)

The small size of *Chelonia mydas* and therefore their weight allow them to crawl to the upper beach. Besides, it had been observed the capacity of this species to jump on small obstacle such as tree log, or beach morphological patterns (micro-cliffs).

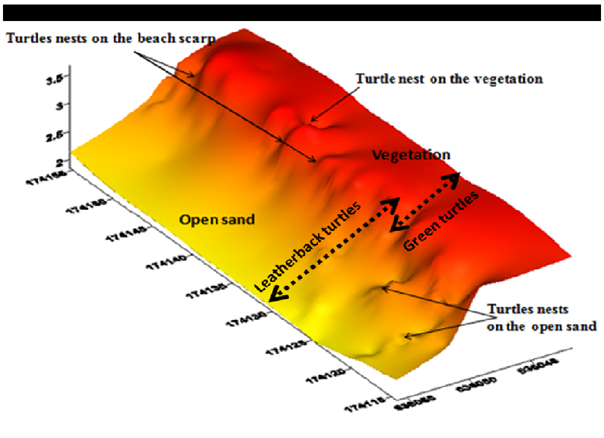

Figure 3: Example of a digital elevation model of a portion of the beach with enhanced position of marine turtles nests and preferred nest location of leatherback and green turtles.

The study highlighted a shift preferred localization of the nesting site by green turtles during the season (chi-square=24.45,p-value <0.001). Between March and May the presence of green turtles was more important near and within the vegetation (17.8% and 41.7%) when the beach scarp was less important and the access to the vegetation was easier for green turtles. From May through July, the number of green turtles nests on the open sand increased (from 40.5% to 62.4%). The main hypothesis to this result can be explain by an amplification of the scarp due to natural erosion induced by waves action and by the marine turtles themselves (figure 3). In fact, the bigger turtles (either green or leatherback) could not reach the upper beach and realize their nests within the micro-cliff.

However, leatherback turtles seem to prefer or to be constraint to nest on the open sand (85,9% and 75,1%) because of their important size they could not reach the upper part of the beach. Different field observations highlight the nest conception within the beach scarp. Two hypothesis could be made : as the turtles could not reach the upper part to nest landward they start to cut away at the beach scarp to collapse it in order to crawl in the vegetation (Witherington *et al.,*2011) some of the turtles succeed but in the major case they started to dig their nests within the sand escarpments and as a consequence an erosion of this section is induced.

Between March through July, a major part of the beach had experienced erosion phases (Figure 4). The beach profile results in typical erosional features such as a scarped profile highlighted by a vertical face (or micro-cliff) and an increasing steepening (Figure 3 & 4). The boundary between sand and vegetation is generally located on the upper part of the beach scarp on scarped profile.

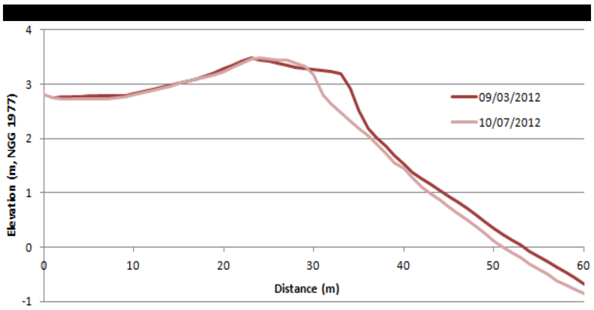

Figure 4: Beach profiles of the beach of Yalimapo on the 09/03/2012 and 10/07/2012.

Leatherback turtles influence

Multiple morphological features along the upper part of the beach resulting from older marine turtles nesting (Figure 5). During the measurement period, one leatherback turtle came to nest on the open sand during the night of the 1st to the 2nd of July (Figure 5b). The next day (the 3rd) the trace of this leatherback nest was totally shifted (Figure 5c). Between the 2nd to the 3rd July, the high tide (hmax= 4m) reached the nest (Figure 5c) and shifted all the nest features.

The macro-bioturbation engendered by the leatherback turtle induced an eroded beach profile between the 1st to the

2nd July (Figure 6). After the passage of the two high tides following the measurement on the 2nd July, the measured on the 3rd July highlighted a restoration of the beach profile around the initial profile (1st July).

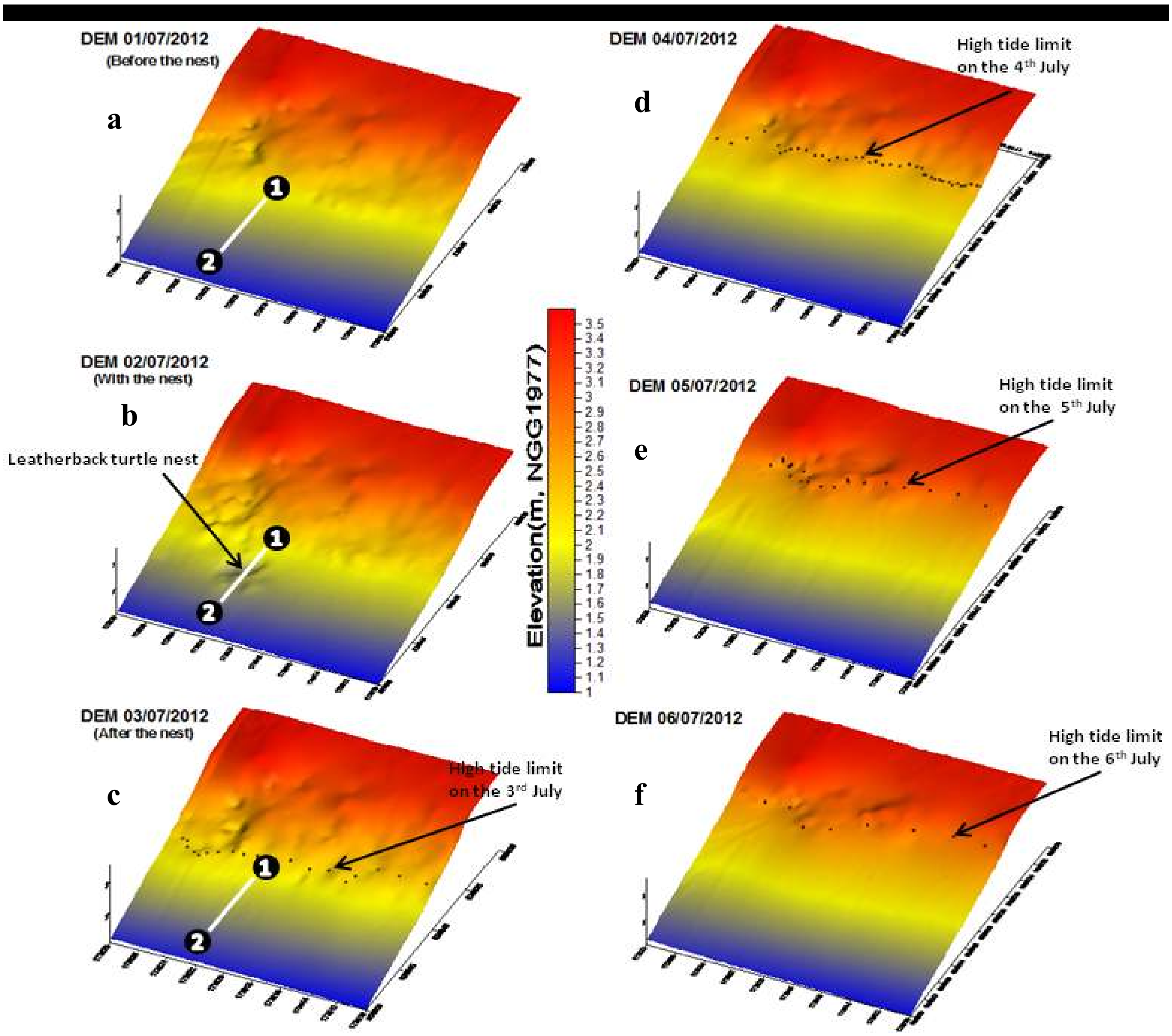

Figure 5 : Digital Elevation Model (DEM) of the study site between the 1st to the 6th July 2012, and the position of the high tide line on the 3rd,4th, 5th and 6th July 2012. The perpendicular transect (1 to 2) corresponded to the beach profiles on a leatherback nests location presented in figure 6.

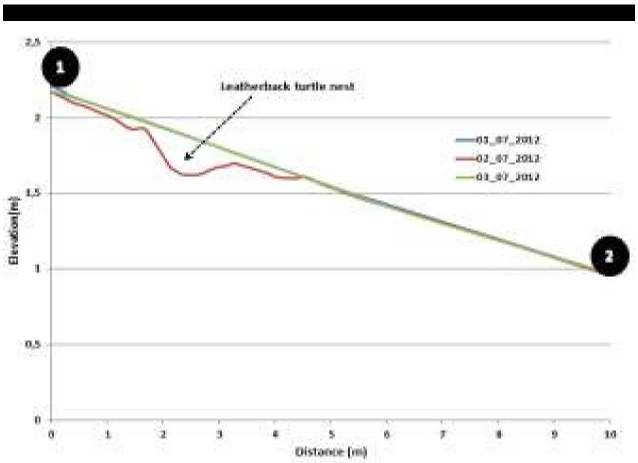

Figure 6: Beach profiles on the leatherback nest the 1st, 2nd and 3rd July 2012, located on the open sand.

Green turtles influence

Almost all the nests realized in the vegetation between March to May (Table 1) are attributed to green turtles (41.7% against 6.2% for leatherback turtles). The nests found in the vegetation (41.7%) during this period had important impact on the backshore morphology. This position induced a protection of the nests, which are sheltered from tidal incursion. In this case, beach morphological changes induced by green turtles remain stable in the vegetation if these nests are not partly destroyed by other marine species that can also come to nest on the same area. Figure 7, presents a comparison of the digital elevation model and a longshore cross section of the beach on the beginning (March), and on the mid-nesting season (May) on the western part of the beach. Between March to May, this part of the beach encountered around 80 nests.

An important evolution of the upper beach morphology was observed. In this case, the impact of turtle nests will produce a much more permanent scar on the morphology of the upper beach which is not submitted to tidal incursion. The longshore cross section on the upper beach (Figure 7c) highlights a smooth morphology of the upper beach in the beginning of the nesting season whereas two months later the upper beach was roughed by the nests conception by marine turtles in the area, therefore the upper beach was marked by strong depression on the beach corresponding to the nests.

However, they are smoothed with time several months after the nests conception by the wind action which tend to erase the salient faces of the nests and by human path (this beach is located in an Amerindian village).

The nest site selection influences the shape of marine turtles nests. When the species attend to dig their body pit within the beach scarp a part of the nest shape will be truncated (Figure 3). These last nests are probably the most effective in the beach morphological changes. They promote the weakness of the scarp which can be rapidly cleared away by the action of the tide and waves.

Green turtles influence on the beach morphological changes is relevant on the upper beach covered by vegetation and on the scarp retreat.

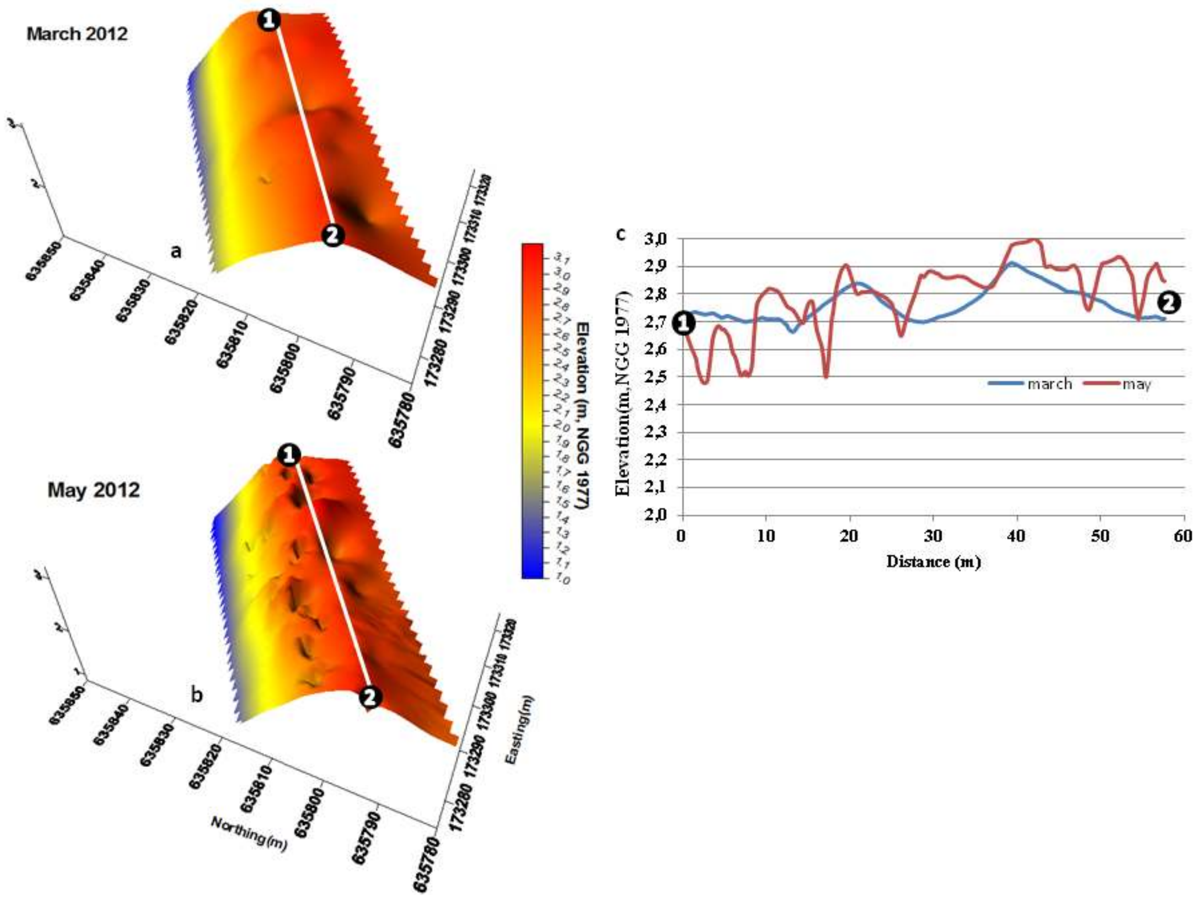

Figure 7: Digital elevation model of a portion of the beach on the (a) 09 march and on the (b) 18may 2012; c/An example of a longshore cross section on the vegetation on the 09 march and 18 may 2012. The transect (1 to 2) corresponded to the longshore beach profile on the upper beach.

CONCLUSION

In this paper, preliminary results of the morphodynamics response of Yalimapo beach to the influence of marine turtles were presented. High-temporal topographic measurements have been carried out to quantify the impact of leatherback and green turtles on their nesting site.

The results illustrate the importance of beach topography on the marine turtles distribution. A major number of green turtles come to nest in the vegetation located in the upper part of the beach which are rarely or never attained by water. This lead to a sustain presence of green turtles nests traces in the vegetation. Whereas leatherback turtles nests as they are located on the open sand are often attained by the waves. This lead to a mobilization of sand around the nesting spot by wave actions. All the nests located above the high tide line are not reach by the water and therefore the morphological changes will be conserve. Comparing the consequences of green and leatherback turtles on the beach morphological changes, we observed that despite the major effect of the leatherback turtles on the beach it appears that the green turtles have more effect on the beach. In fact, the two species act at two different spatial and temporal scales. Modification on the beach induced by the nests depends on the localization. When the nests are situated in the intertidal area a restoration of the beach profile by wave action is observed and the nesting features are erased by a redistribution of the mobilized sand. These erasing processes appear when the nests are attained by water and much more significant during spring tide. Nevertheless, nests morphological features could remain on the lower upper part of the beach during several days after the nesting events during the spring-to-neap decrease in tidal range.

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