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Coastal erosion and village relocation: a Colombian case study

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Abstract

Because of its tectonic setting, the Pacific coast of Colombia is subject to a variety of geological hazards, including earthquakes, tsunamis and associated phenomena such as regional and local coastal subsidence, flooding and soil liquefaction. Erosional trends are prevalent along much of the 700 km long, low barrier island's shorelines of the Pacific littoral and land losses are enhanced by factors such as 30 cm regional sea level rises associated to the occurrence of El Niño. Marine erosion is threatening more seashore littoral villages and worsening the already difficult socioeconomic conditions of most part of the inhabitants. Because of diverse and strong motivations to stay near the sea, the responses of barriers island's inhabitants to marine erosion has consisted in most cases of repetitive in-shore and along-shore directed relocations of villages, rather than definitive abandonment of the islands. In the long run, this procedure only has postponed the problem and led to repetitive relocations and economical losses. The recent inland relocation of El Choncho village, on the San Juan River delta, illustrates a different response to marine erosion. Although a new along-shore relocation was physically possible, inhabitants decided to abandon the barrier island and migrate to an interior, ancient beach ridge complex, applying a prudent solution which will be the most appropriate for other threatened villages of the Pacific littoral. A detailed geomorphologic mapping program must be conducted in order to identify appropriate sites for inland relocation of existing villages on the barriers islands of the Colombian Pacific coast.

1. Introduction

The Pacific coast of Colombia, located at the northwestern corner of South America (Fig. 1), is legendary for its luxuriant vegetation and rainy humid tropical

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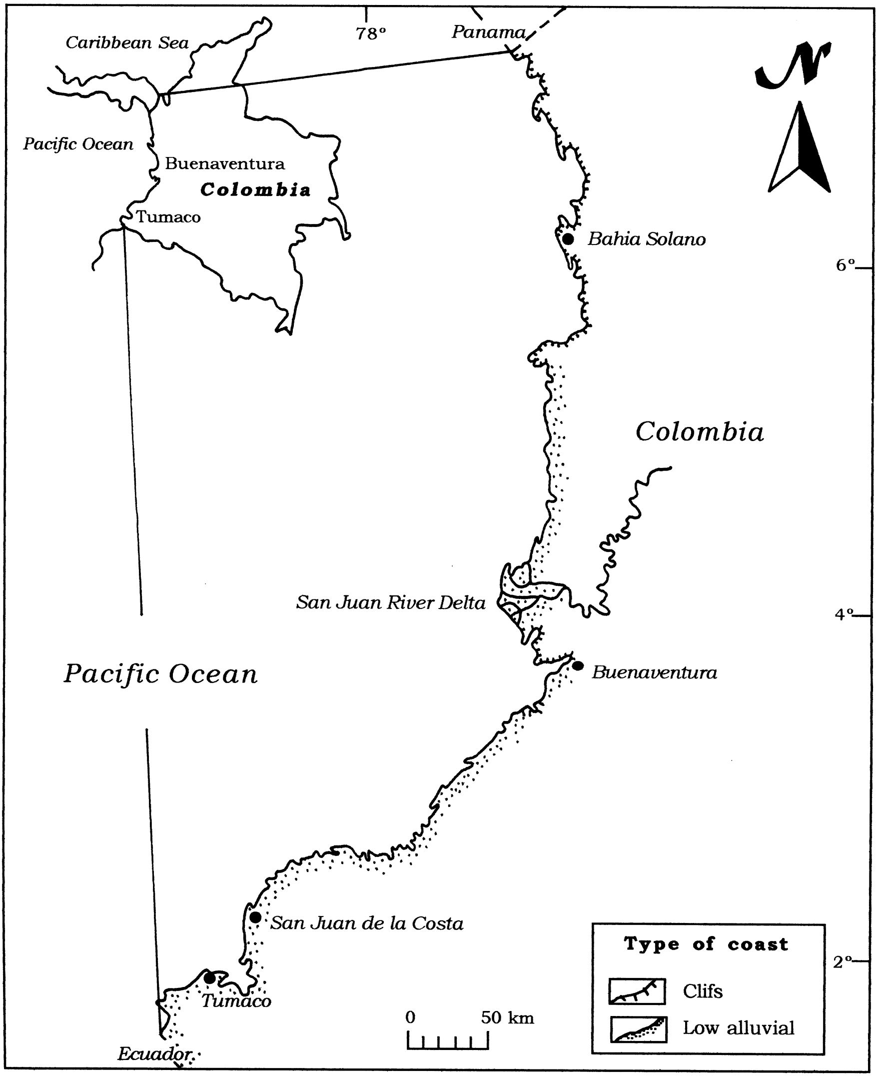

Fig. 1. Location map of the San Juan River Delta on the Pacific coast of Colombia.

climate. This largely isolated region lacks the basic infrastructure facilities in most areas: road access is limited to two highways that connect the interior of the country with Buenaventura and Tumaco (the only two commercial seaports on the Pacific) and air access is available only to a few cities in the region; to reach most parts of its 1300 km length littoral, it is necessary the use of small boats, navigating both by sea and/or by the dense networks of fluvial and tidal channels crossing the coastal zone. The socioeconomic conditions of the region are poor, the economy for most of the

Fig. 2. Photograph of non-storm washover El Choncho. Note the lack of high waves in the Pacific or strong onshore winds.

inhabitants is subject to daily subsistence with the basic necessities far from being adequately covered. Traditionally, the main economic activities have been timber exploitation, fishing, shipping and gold mining, concentrated around the influential areas of Buenaventura, Tumaco and other smaller development centers. In the last decade, shrimp aquaculture and eco-tourism became important in some sectors of the coastal zone.

Located at the zone of convergence of the Nazca and South American plates [1–3] the Pacific coast of Colombia has a long history of natural disasters, including four earthquakes of magnitude 6.5 or larger in this century [4–6]. The Tumaco, December 12, 1979 earthquake, was the last major impact event on the southern Pacific coast of Colombia. It generated a sudden land subsidence estimated in 1.6 m along the littoral zone and a large tsunami that completely destroyed several small villages along the sandy barrier islands north of Tumaco. San Juan de la Costa, an open coast fishermen village located 60 km north of this city was literally buried by a 3 m high water column which drought at least 156 inhabitants; the port of Tumaco, with a population of 25 000, did not suffer the direct impact of the tsunami because of some geomorphological protection and because the tsunami struck at low tide [7].

Although less impressive, the impacts of long-term shoreline retreat are acquiring first-order socioeconomic importance along the Pacific littoral. Given the growing number of coastal villages exposed to marine erosion and the limited areas of high ground on the barrier islands, the need for implementing valid strategies to cope with the shoreline erosion and flooding problems is evident (Fig. 2). For the small and poor communities located along the retreating shorelines, agricultural lands are rapidly diminishing as a result of land losses and associated effects such as soil salinization. At the end, relocation is and will be the sole possible response to beach retreat, but where and when to relocate has not always been clear or properly done.

The case of El Choncho village, a community located on the coastal fringe of the San Juan River delta, illustrates an example of the socioeconomic consequences of marine erosion along the Pacific littoral, and the human and geomorphologic factors involved in the decision for relocating. This case represents a long-term perspective which should be taken as an example of the correct response to shoreline retreat for

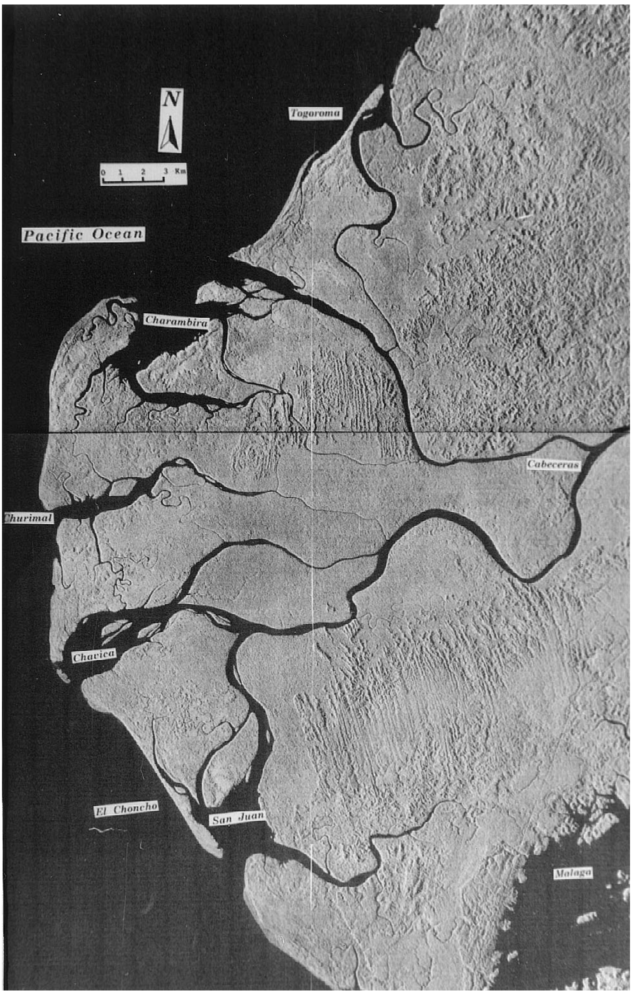

Fig. 3. Radar image of the San Juan river delta. The location of villages on barrier islands is indicated. INTERA image from 1992. Courtesy of INGEOMINAS.

other coastal communities along the low deltaic sectors of the Colombian Pacific coast.

2. General setting

Before its definitive relocation in 1997, El Choncho village was located on the El Choncho barrier island, the southern most sandy active barrier of the San Juan delta (Fig. 3). Located 90 km north of Buenaventura, the delta has a well-defined protruding lobate form with an emergent area of 800 km^2 and a shoreline length of 51 km. The San Juan river has a course length of 345 km and a basin area of 17 000 km^2, the second largest of the Colombian Pacific coast. Mean annual precipitation in the basin ranges from 6 to 7 m, with a reported maximum of 11 m/yr near the head waters [8]. The San Juan river has the highest discharge of any river on the Pacific coast of South America, a mean of 2850 m^3/s and a range between 600 and 6000 m^3/s, measured at Cabeceras, 5 km upstream from the delta apex [9]. No individual discharge figures are available for each of the six active inlets of the delta.

The lower delta plain extends landward for 6–11 km and is under the direct influence of tidal effects as evidenced by extensive mangrove intertidal flats and by a dense network of meandering tidal channels. Four sandy barrier islands, ranging in length from 7–12 km and in width from 80–300 m, define the seaward limit of the lower delta plain. Some of these barrier islands have well-developed beach ridges with maximum elevations of 1 m above spring tides. Former shoreline positions north and south of the delta plain are identified by remnants of older beach ridges and barriers with an orientation roughly parallel to that of the present day shoreline.

Around the San Juan delta average spring tides have a range of about 4.0 m [10]. Dominant wave directions are from the west and southwest; wave energy is moderate with wave lengths of 10–50 m and average wave heights of 0.5–1.5 m; storm wave heights range from 1.5–3.5 m. As evidenced by the morphology of spits on barrier islands, wave refraction is divergent at the axis of the delta and net longshore drift along the delta is both south and north away from the axis. El Niño occurrences along the central and south Pacific coast of Colombia are manifested by an increase in sea level of as much as 25–35 cm [11,12] (Fig. 4).

3. The community of El Choncho

The occupation of El Choncho barrier island dates back to 1906 when the first inhabitants settled and raised pigs that were let to run free along the island. The number of pigs was large and that is the origin of the island's name; *choncho* is a Spanish word for pig. Occupation since 1906 has been continuous. The island was known up to the 1970s for its numerous crops that included several basic agricultural products for self-subsistence including rice, avocados, cassava roots, plantain banana, oranges, mangoes and coconuts. "We did not have to worry about food at that time" an old inhabitant told us, in reference to the fact that they did not need to import food.

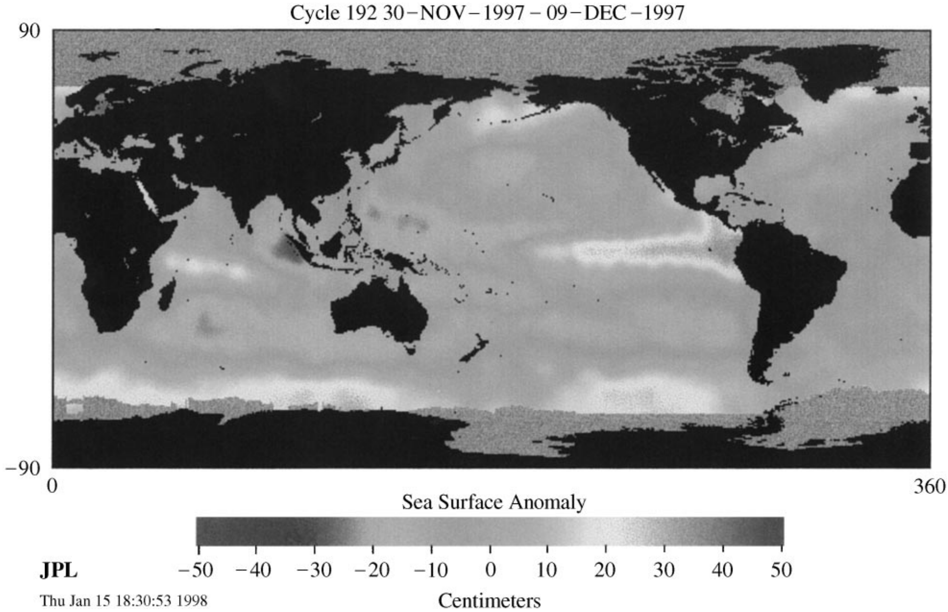

Fig. 4. Topex/Poseidon Image. Cycle 192 from Nov/30/97 to Dec/09/97. During this period sea level for the west coast of northern South America was between 30 and 40 cm higher than normal, due to an intense El Niño event. These data were obtained from the NASA Physical Oceonography Distributed Active Archive Center at the Jet Propulsion Laboratory, California Institute of Technology.

At this time, the economy of El Choncho was mainly based on the exportation of agricultural products (the village was famous by its fruits) and the exploitation of timber and fishing. Some inhabitants received additional income by keeping and maintaining several vacational beach homes owned by people from the interior and by providing shelter for sporadic tourists and occasional research teams working in the area. In a simple economy with non-accumulative prospects, most villagers used their income to improve their living conditions. Individuals seeking better economic possibilities migrated to Buenaventura and other bigger coastal communities.

A typical house in the old El Choncho village was built of wood, elevated on stilts at heights of 1.5 m above the ground to accommodate flood and washover potential. They had a tin roof from which rain water was collected for domestic use; septic tanks were used to discharged waste water.

4. Chronology of island erosion at El Choncho

Like all the delta barriers and other barrier islands along the Pacific littoral, El Choncho island experienced important morphological changes in recent decades. The recent shoreline changes along the barrier's front were documented by comparing air

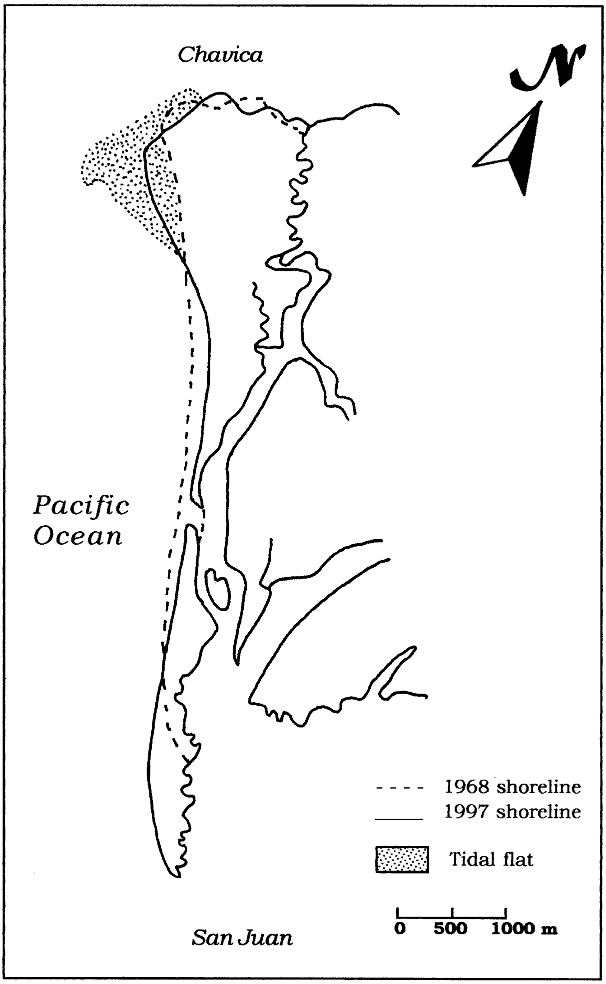

Fig. 5. Representation of shoreline changes between 1968 and 1997 for El Choncho barrier island.

photographs and radar images from 1968 to present [13,14] and by interviewing the long time inhabitants of the island. During this period, the island's front position and configuration changed significantly as reflected by (a) the formation of an extensive sandy cuspate tidal flat at its northern end, (b) the development of a 1.5 km long beach ridge system on its southern end, and (c) a total beach retreat of between 150 and 220 m along the 2 km long central segment of the island, on which the El Choncho village and related agricultural plots were located (Figs. 5 and 6).

It is not known exactly when beach retreat started along the central part of the island, but the first oral references of noticeable 1.5 m high permanent erosional beach scarps in front of the village area date back to 1970–1975, suggesting preexisting

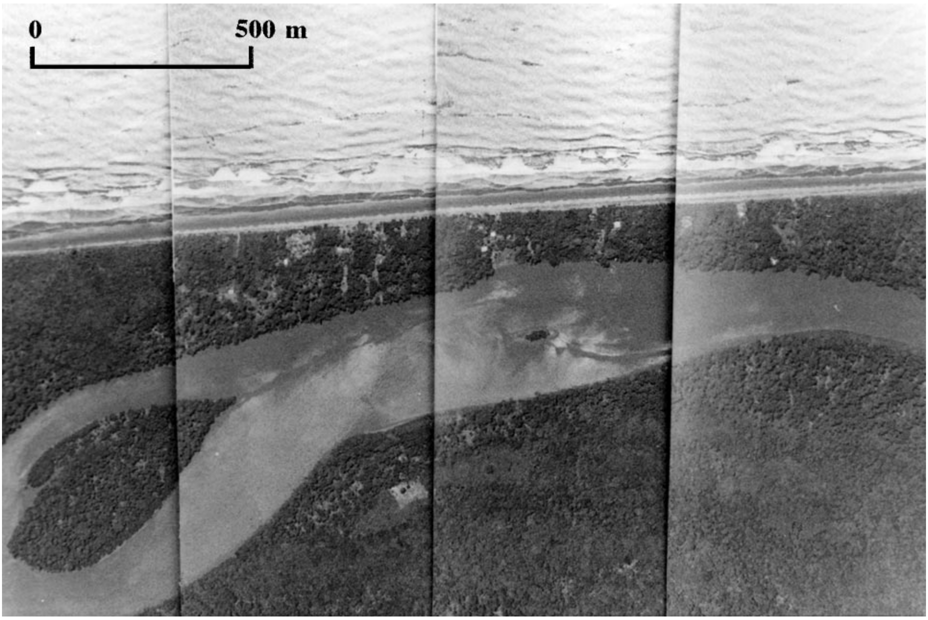

Fig. 6. Air photo from 1993, showing the central part of the El Choncho Barrier Island, where the village was located. Note width of island. At that time it was 110 m at the narrowest part. Also note the houses dispersed on the front of the island. By this date all houses had been relocated at least one time, towards the landward side of the island.

erosional conditions at that time. The development and emergence of the sandy cuspate tidal flat on the northern end of the island predates the 1968 photographs; the tidal flat trapped the sand drift and promoted erosional conditions in a downcurrent direction on the island front. The normal annual cycle of beach changes on the island's central part was one of beach retreat during October–November, and partial beach recovery between January and April. Intense erosion affecting the seaside houses of El Choncho village was first measured in 1989, beach retreat of 15 m between October 1988 and September 1989 was well documented [15,16]. Erosion rates in front of El Choncho accelerated after the occurrence of the November 1991 magnitude 6 earthquake with epicenter just 40 km to the NW of the delta [17]. On El Choncho village, the direct effects of the shock included soil liquefaction, land cracking and water–soil expulsion. Although no quantitative estimates are available, land subsidence effects are evidenced by the fact that the frequency of overwash on the island increased two times a year (March and October during the highest tides) before the quake, to at least once a month after the shock. According to inhabitants, the normal beach cycle was disrupted by the event and erosional conditions prevailed throughout the year. Beach erosion between April 1993 and November 1997 is well documented by topographic profiles that show a net beach recession of 60 m with an average rate of 11 m/yr for this period (Fig. 7).

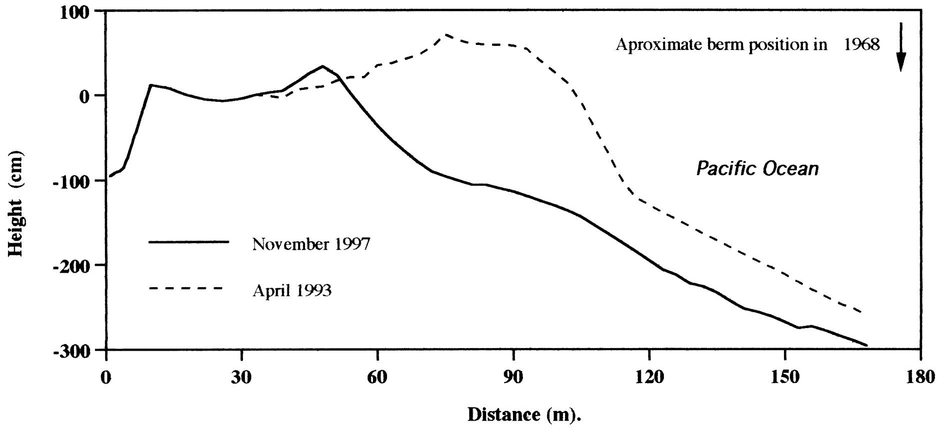

Fig. 7. Topographic beach profiles at the location of El Choncho village. A net retreat of 60 m of island front between April 1993 and November 1997 is clearly seen.

The central part of the barrier was breached in June 1996, during an exceptionally high tide. The island was incised by a small channel, 5 m wide and less than 1 m deep, located just beside the northernmost house of the village. The channel grew rapidly with each high tide and by December of that year it became a true inlet, 30 m wide and several meters deep. By May 1997 the inlet had migrated to the south and had a width of 50 m and a depth of 10 m. Strong bi-directional tidal circulation deposited a large ebb tidal delta in front of the inlet, and sand drift to the south of the island became even more disrupted. In December 1997, flooding along the central part of El Choncho destroyed several houses and by February 1998 the area where the village was located was completely underwater. From May to December the equatorial Pacific coast was under the influence of El Niño with sea level 30–35 cm higher than normal (Fig. 4). The high sea level was responsible for the flooding, as well as the accelerated erosion and the rapid migration on the inlet [12].

5. Definitive relocation

Between 1970 and 1988, El Choncho's agricultural land and the majority of the summer homes had been gradually lost to beach erosion. During this period a first relocation of the village took place to the island's interior. By 1992, El Choncho's economy had deteriorated to the point where all the food had to be imported and the only sources of income were fishing and timber. Timber activities had become increasingly difficult because of over-exploitation and new environmental regulations. At this time some people left the island seeking new opportunities elsewhere.

From the date the barrier was breached, June 1996, islanders realized that relocation was absolutely necessary but the process did not take place immediately because

Fig. 8. Air view of the new El Choncho village 6 months after construction had started. Note the typical vegetation and well drain sands from the beach ridge complex contrasting with surrounding tropical rain forest and mangrove swamps. View is to the East.

of a combination of lack of consensus about the new site, the scarcity of economic resources and the hope, by some, that the erosional trend would stop. At that time the first option considered was to remain on the island and to move along-shore, either to the NW, away from the direction of inlet migration, or to the SE, to a wider portion of the island. By the beginning of February 1998, inlet migration and beach retreat intensified dramatically due to a combination of high tides and higher than normal sea level, and the remaining homes that were still occupied were destroyed within two days. The intensity of the flooding and the rapid beach retreat made the community change their mind and decide that the wisest option was to leave the island and relocate at the interior of the delta, option considered so far as a secondary one. Consensus was quickly reached to rebuilt on the nearest interior and sandy beach ridge complex known as "Santa Barbara beaches", 200 m inland of the original location and across the tidal channel (Fig. 8). Not affected by marine erosion, the "Santa Bárbara beaches" offered the nearest to the sea stable setting with access by boat at any tide stage and soils with some possibilities for basic agriculture. The reconstruction process started in mid-February and by August 1998 most families had completed building their houses in the new village. The only governmental help provided was construction materials and all the construction work was made solely by them.

6. Discussion

The El Choncho village relocation illustrates some typical effects of the extensive, long-term shoreline erosion along the 700 km length low segments of barrier islands along the Pacific littoral of Colombia. This situation is most likely to continue and worsen in the future because of a combination of factors including global sea level rise, earthquake induced and or compactional subsidence, tsunamis and occasional higher than normal sea levels associated with El Niño [12,14,18,19].

This is not, however, the most dramatic case along the Pacific barrier islands of Colombia, as evidenced by the earthquake/tsunami brutal destruction of San Juan de la Costa on December 12, 1979, for which quantitative figures of local and regional subsidence were measured immediately following the earthquake: as much as 1.6 m of sudden subsidence occurred along a 200 km segment of coastline and figures of 50–60 cm were reported for localities 20 km inland from the coast [7,20]. That subsidence dramatically augmented an already existing regional erosional trend on the southern Pacific coast of Colombia. Although no figures of earthquake-related subsidence exist for the north and central Pacific coast, the case described here and the testimonies of inhabitants of other erosion threatened villages strongly suggest that erosional conditions have been triggered or accelerated by earthquake-generated subsidence, as was the case for several villages to the north of the San Juan delta in connection with the 1970 Bahía Solano earthquake [21]. Erosional vulnerability of barrier islands of the Pacific littoral is increased during periods of El Niño which raises sea level for several months. During the 1997–1998 El Niño, a 35 cm sea level rise incremented erosion rates along the already erosive shores. In a complex physical framework such as this, modelling the evolution of coastal areas and predicting shoreline evolution trends is a giant task far from being accomplished.

Socioeconomic effects of barrier island erosion are short term and drastically disrupt the *modus-vivendi* of islanders. The main economic advantage of living on the widest barrier islands of the Pacific coast is the possibility of being almost self-sufficient in basic food resources and supporting a small economy with surplus goods. The loss of coastal lands in recent decades has eliminated this possibility for many barrier islands of the Pacific coast, so islanders are more dependent on fishing and timber exploitation. This last resource is however rapidly decreasing in view of the absence of reforestation programs, they have to travel farther distances every day in order to obtain timber and that causes displeasure by the inhabitants surrounding those areas. Migration of barrier islands's inhabitants to large cities of the interior reflects in part the diminishing of resources both in and around the littoral zone, part as a consequence of marine erosion. For a population composed mainly of blacks and indians, lacking basic education, the prospects of living in such centers are far from adequate.

The relocation process of El Choncho is to our knowledge unique along the Pacific coast, in the sense that the decision to relocate inland was taken by the community when relocating on the barrier island was still possible. Such voluntary relocation has not been the case in neighboring villages threatened by erosion. Examples on the San Juan delta include the cases of Charambira and Togoroma, where inland relocation took place only after several along-shore relocations failed at a high cost in resources and time. The recent history of San Juan de la Costa illustrates the extreme case: immediately after the destruction of the village, the government promoted an inland relocation which was undertaken. Within five years, islanders, unsatisfied in the new location, returned to the barrier, disregarding the previous disaster and increased risk. Continued shoreline retreat created a situation similar to El Choncho, and during the 1997–1998 El Niño, the village had to be again relocated to the interior.

The decision to relocate on the mainland taken by the community of El Choncho was not an easy one because the option of remaining on the barrier was driven by very strong and diverse motivations, basically cultural factors established by nearly a century of island occupation. Among other factors, living closest to the sea is strategically important because:

- The villagers know at any time the sea and weather conditions in order to plan activities.
- The possibility of having eye contact with fishing teams at a short distance offshore exists.
- Being aware of travelers along the coast allows villagers to be or to demand assistance in an emergency (there are no radio or telephone communications in the El Choncho barrier island and adjacent areas).
- A minimum tourist infrastructure had been developed as a source of income; an important alternative considering that the two main economic activities, fishing and timber, were becoming increasingly difficult.
- Directly facing the sea takes advantage of the sea breeze for a more comfortable climate and to keep malaria transmitting mosquitoes away.

People in the new village are adapting to their new living conditions. Basic agriculture provides some help, but the Santa Barbara beaches are far from providing the same agricultural possibilities as El Choncho barrier island did and tourism income is now practically absent, reducing strongly the economical perspectives for them. Help has been demanded from the government in order to obtain technical training and modern means for increasing the fishing capacities, which has become the main activity by now. Not having direct, visual contact with the sea has been particularly difficult for many of them and the feeling of isolation is common, specially for women.

The example provides some of the basic facts and antecedents that Coastal Zone Management will have to be consider in the future, when governmental agencies have the capacity for planning and regulating the development of the Pacific coast littoral zones. In terms of immediate Coastal Zone Management priorities, it is obvious that present shoreline erosional trends and tsunami risk along Colombia's Pacific coast are factors which strongly support inland relocation of littoral villages as soon as possible. A systematic program of large scale geomorphologic mapping in search of appropriate inland sites for relocation should be the first priority of concerned agencies. To improve the socio-economical conditions of barrier island inhabitants of the Pacific littoral of Colombia is certainly the another priority faced by the Colombian government. Appropriate relocation strategies are just the first steps in that direction.

Acknowledgements

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