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Type, distribution, and origin of sediments of the Gandoca-Manzanillo National Wildlife Refuge, Limón, Costa Rica

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Abstract: Sediments and the marine current system at the Gandoca-Manzanillo National Wildlife Refuge, Caribbean coast of Costa Rica, define two sedimentary environments. One between Punta Uva and Manzanillo, where sediments were derived from the coral reefs and local geological formations. The other lies between Punta Mona and Río Sixaola, where sediments arrive primarily from outside the area. Fine-grained sediments were collected off rivers and creeks mouths, and adjacent beaches. The highest percentage of carbonates (60 to 80%) was found off Punta Uva, and consisted mainly of mollusk, algal and coral fragments, and Foraminifera. Magnetite found in large quantities off Manzanillo, and also observed on the beach, was derived locally from the Río Banano Formation. Clay and silt were found in high concentrations from Punta Mona to Río Sixaola. Other minerals, pyroxene and hydrobiotite, probably originated from the erosion of intrusive rocks cropping out in the central section of the Talamanca Range. The sediment plume of Río Sixaola extends several kilometers off shore, flowing northwest and affecting coral reefs off Punta Mona. Other areas of the Refuge are not exposed to high concentrations of terrigenous sediments. However, as a result of deforestation, new constructions and removal of riparian and coastal forests, more coral reefs of the Refuge will be affected by sediments.

Key words: Reef sediments, Gandoca-Manzanillo, Costa Rica, Wildlife Refuge.

The study of sediments in coral reef areas can provide information on sediment origin (Matson 1989), the relationship between sedimentation and reef community structure (Boss & Liddell 1987), the transition from siliciclastic to carbonate sediments (Acker & Stearn 1990), and the relationship between sediment distribution and marine currents (Kleypas 1996). These studies are particularly important when sedimentation is affecting reef growth and development (Cortés & Risk 1985, Rogers 1990, Kleypas 1996).

Sediments present in the Gandoca-Manzanillo National Wildlife Refuge, Limón, Costa Rica, were initially studied by Cortés (1992) as part of a basic survey of the Refuge. Later, Heikoop and Risk (1993) analyzed beach sediments between Manzanillo and Punta Uva. In this paper, we expand on their observations and we relate these sediments to their sources and to the general current system at Gandoca-Manzanillo National Wildlife Refuge.

MATERIALS AND METHODS

Fourteen sediment samples were collected by SCUBA diving between Punta Uva and the Panamanian side of Río Sixaola (Fig. 1). Samples were removed from the top 10 cm of

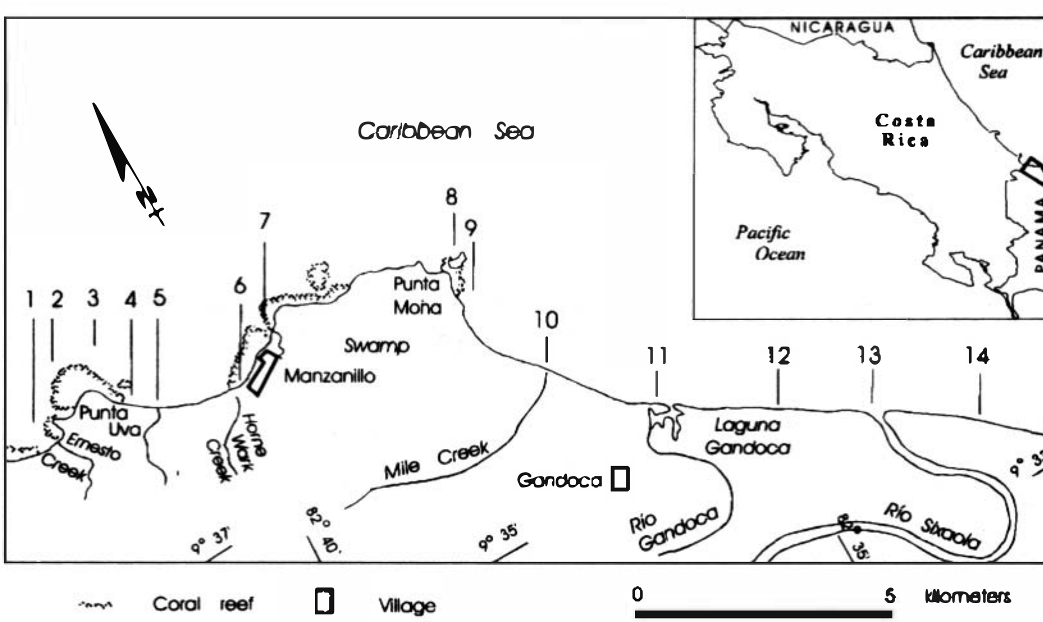

Fig. 1. Sampling sites at Gandoca-Manzanillo National Wildlife Refuge, Province of Limón, and location of the refuge on the Caribbean coast of Costa Rica.

the bottom, approximately 100 m from shore.

Grain size distributions were determined by standard sieve technique with the following sieve sizes: 4 000, 2 000, 1 000, 710, 500, 355, 250, 180, 125, and 63 µm (McManus 1988). All analyses were done in duplicate or triplicate. The percent of calcium carbonate was calculated by the weight lost method (Seisser & Rogers 1971).

Sediment samples retained by the 420, 250, 149 µm sieve sizes were analyzed. The basic components (organisms, lithic, and mineral fragments) were identified using a binocular microscope. A representative fraction of the retained material was extracted from each sieve in order to count the mineral components. Each component was separated and the grains counted to determine the percentile relation in each sieve. This percentage was extrapolated to a percentage in relation to the total weight using the cumulative frequency distribution curve of grain size diameters previously determined. The number of grains per sample used to obtain the final results varied from 225 to 1350.

RESULTS

Fine-grained sediments present in the Gandoca-Manzanillo National Wildlife Refuge, containing a high concentration of non-carbonate material, were found off rivers and creeks mouths, and on beaches in between (Fig. 2, 3). The larger grain sizes were found in reef areas, where the carbonate fraction is also higher (Fig. 2, 3).

Sediments were composed mostly of carbonates, magnetite, and lithic fragments (Table 1). The highest percentage of carbonates was found off Punta Uva and other reef areas (Fig. 3). The main components are mollusks, algae (mainly *Halimeda* and *Amphiroa*) and coral fragments, foraminiferans, and unidentified carbonate particles (Table 1).

Magnetite was found in large quantities off Manzanillo, and was also observed on the beach (Fig. 3). Magnetite is also present offshore from creeks draining the inner swampy area of Punta Mona, and at the mouth of Río Sixaola (Fig. 3).

In general, the siliciclastic components of the sediments are also more abundant offshore

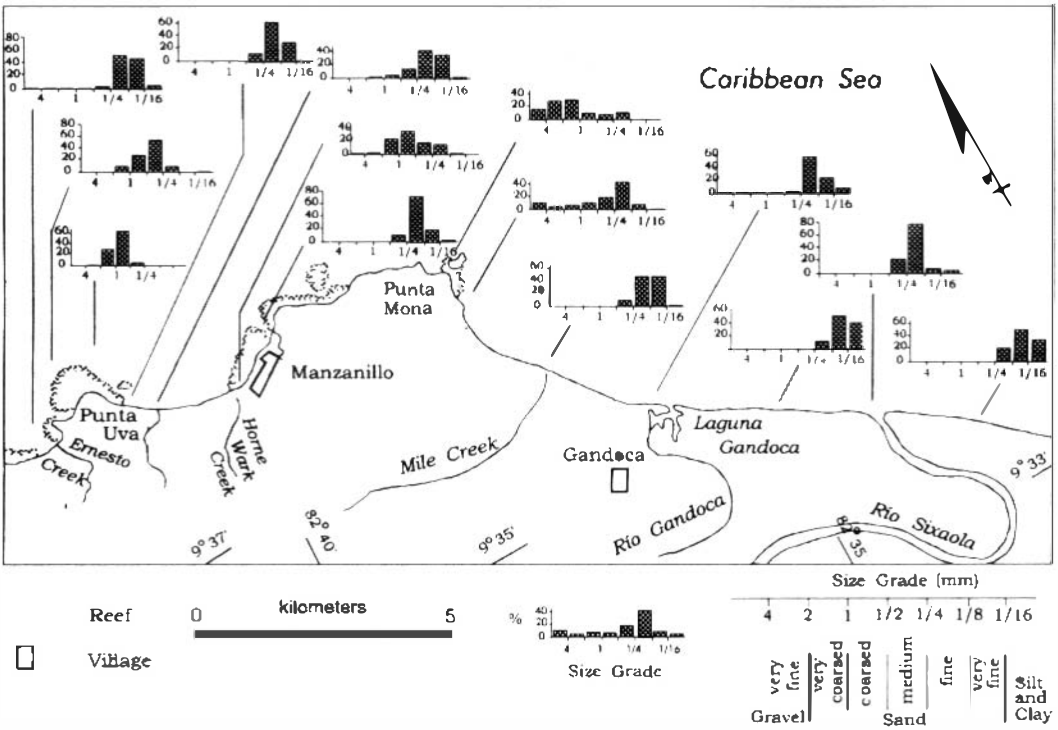

Fig. 2. Grain size distribution of the sediments collected at the Gandoca-Manzanillo National Wildlife Refuge.

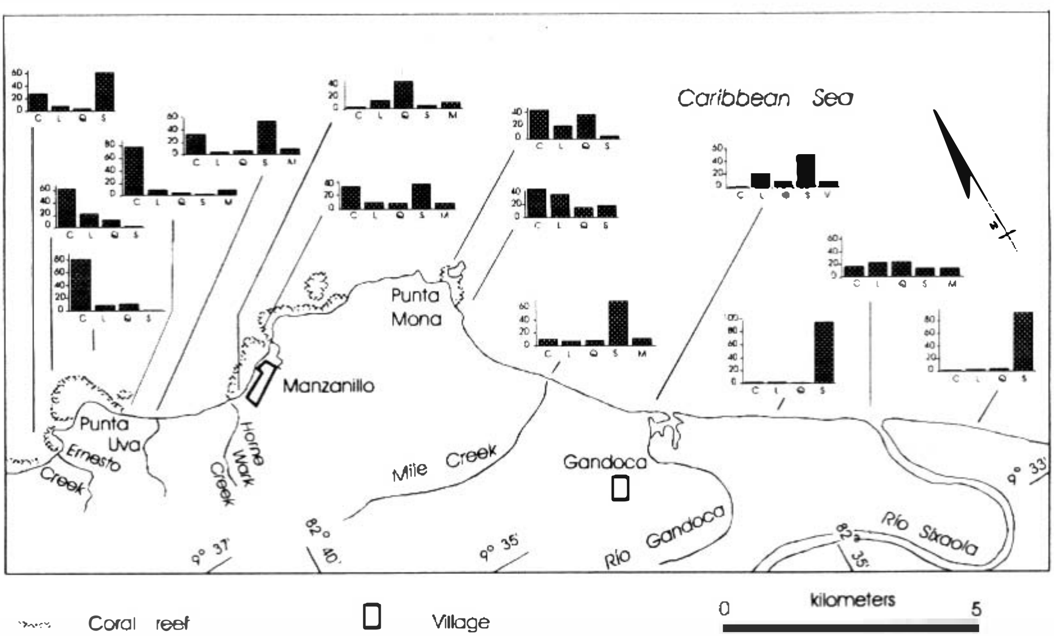

Fig. 3. Percent composition of the sediments from the Gandoca-Manzanillo National Wildlife Refuge. C = carbonates; L = lithic and mineral fragments; Q = quartz; S = clay, silt, and very fine sand; V = plant detritus; M = magnetite.

TABLE 1

Composition of the sediments from Gandoca-Manzanillo
Sample location in Fig. 1

Sample	Minerals and lithic fragments: Igneous Minerals				Lithic fragments			Organic fractions				
	Magnetite	Pyroxene	Hydrobiotite	Quartz	Intrusive	Sedimentary	Volcanic	Mollusk	Coral	Spicules	Foraminifers	Others
1	x	x	x	x	x	x		x		x	x	x
2				x		x		x	x		x	x
3	x	x	x	x	x		x	x	x	x	x	x
4	x	x	x	x	x	x		x	x	x	x	x
5	x	x	x	x	x	x	x	x	x	x	x	x
6	x	x	x	x	x	x	x	x	x	x	x	x
7	x	x	x	x	x	x	x	x	x	x	x	x
8		x	x	x	x	x		x	x	x	x	x
9	x	x	x	x	x	x	x	x		x	x	x
10	x	x	x	x	x	x		x				x
11	x	x	x	x	x	x				x		x
12	x	x	x	x	x	x	x					x
13	x	x	x	x	x	x	x					
14	x	x	x	x								x

from rivers and creeks. Samples from those areas also had few animal remains, and a high percentage of the mollusk shells showed signs of dissolution. The sample from Laguna Gandoca had a high percentage of plant detritus (Fig. 3), indicating that the beach sill, which seals the river mouth, is sometimes broken.

The sediment plume of Río Sixaola extended several kilometers offshore, had a high concentration of suspended sediments (over 2 g/l) and flotsam (leaves, trunks, fruits, garbage), and a relatively low temperature (24.5°C), compared to adjacent marine waters (28°-30°C).

DISCUSSION

The composition of the sediments at Gandoca-Manzanillo National Wildlife Refuge was a mixture of organically and physically derived sediments from the coral reefs (carbonates), and terrigenous siliciclastic sediments from the coastal formations and from the mountains inland. Sediment composition at a particular locality was also controlled by drainage streams inland and marine currents offshore.

The Río Banano Formation, which crops out along the Caribbean coast, was probably the main source of magnetite present on the coastal zone. Large accumulations of magnetite were observed not only at Gandoca-Manzanillo, but also on beaches north of the area, locally called "black beaches".

The presence of lithic fragments (intrusives and volcanics) and of minerals like quartz, pyroxene and hydrobiotite (Table 1) indicate that they probably came from intrusive and volcanic rocks of the Talamanca Range, rather than Tertiary sedimentary formations (Río Banano and Uscari). The presence of resistant igneous minerals such as quartz, together with less resistant minerals or minerals more susceptible to alteration (e.g. pyroxene), indicate a rapid transport from the mountain range to the coast. This rapid transport was also evidenced by the fact that the eroded and transported igneous and volcanic fragments have mineral compositions similar to the individual minerals found in outcrops.

The main current along the Caribbean coast of Costa Rica moves from northwest to southeast (Roberts 1997), creating small eddies in the other direction (Fig. 4). One of these eddies transported sediments of Río Sixaola northwest along the coast (Fig. 4), which were affecting reefs off Punta Mona (Cortés 1992). The current just north of Punta Mona (Fig. 4) was strong and moving to the southeast, so sediments from Rio Sixaola do not reach beyond that point (Cortés 1992), as indicated by Heikoop and Risk (1993).

The southeast current also creates an eddy in front of Manzanillo, moving sediments from east to west, between the town and Punta Uva (Fig. 4). The longshore drift transports magnetite from Manzanillo and nearby creeks to Punta Uva, as observed by Heikoop & Risk (1993).

The coastal current system south of Punta Mona has caused a decrease in carbonate content southward from Punta Mona, as fluvial contributions increase. This may explain why clay, silt, and lithic fragments were found in larger concentrations from Punta Mona to the mouth of Río Sixaola (Fig. 3).

CONCLUSIONS

The origin of the sediments and current system at the Gandoca-Manzanillo National Wildlife Refuge define two sedimentary envi-

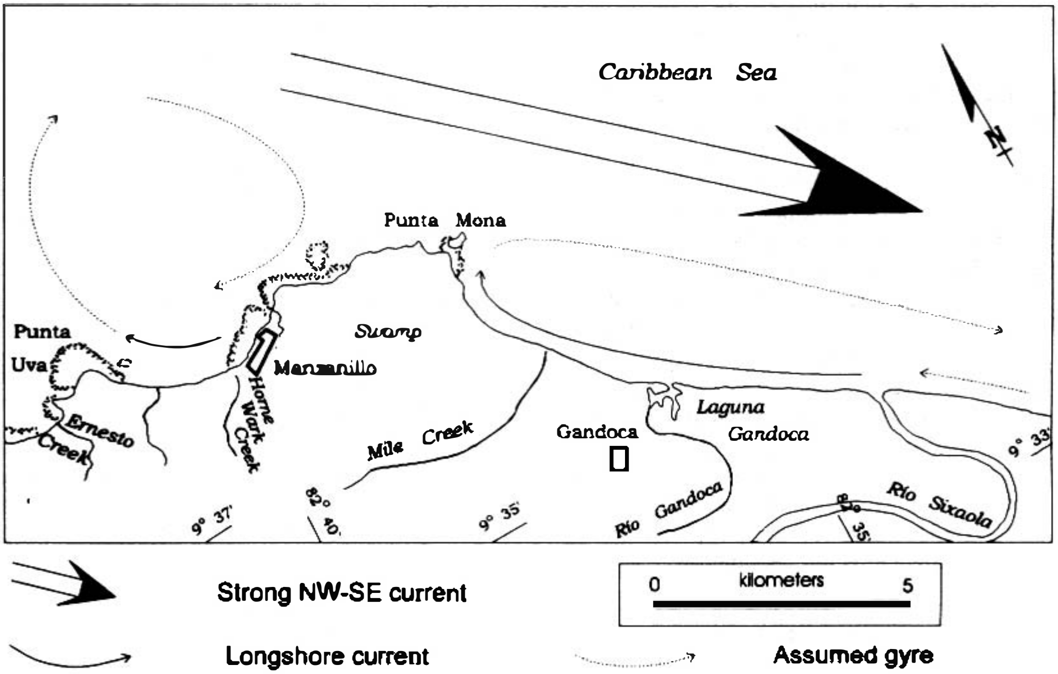

Fig. 4. Current system at the Gandoca-Manzanillo National Wildlife Refuge.

ronments. The first extends from Punta Uva to Manzanillo, where sediments consist of carbonates, locally derived from the coral reefs, and magnetite, locally derived from the Río Banano Formation. The other sedimentary environment lies between Punta Mona and Río Sixaola. The few carbonates in those sediments are derived from coral reefs at Punta Mona. The main sediment fractions, terrigenous in origin, come from outside the area, transported by Río Sixaola.

Coral reefs at Punta Mona are being affected by terrigenous sediments derived from Río Sixaola (Cortés 1992). Other areas of the Refuge are not exposed to such high concentrations of terrigenous sediments. However, as regional land use is been modified by deforestation, new construction, and removal of riparian and coastal forests, more coral reefs of the Refuge will be affected by sediments.

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RESUMEN

El origen de los sedimentos y el sistema de corrientes en el Refugio Nacional de Vida Silvestre Gandoca-Manzanillo definen dos ambientes sedimentarios. El primero, entre Punta Uva y Manzanillo, donde los sedimentos se originan en los arrecifes coralinos y las formaciones geológicas locales. El otro, entre Punta Mona y el Río Sixaola, donde los sedimentos se originan principalmente fuera del área. Se recolectaron sedimentos finos en la boca de los ríos y quebradas, y en las playas adjacentes. El porcentaje más alto de carbonatos (60 a 80%) se encontró en Punta Uva,

y consiste principalmente de fragmentos de moluscos, algas y corales, y foraminíferos. Se encontró magnetita en grandes cantidades frente a Manzanillo, y en la playa; derivada localmente de la Formación Río Banano. Arcillas y limos son abundantes desde Punta Mona hasta el Río Sixaola. Otros minerales, piroxena e hydrobiotita, probablemente son producto de la erosión de las rocas intrusivas que afloran en la sección central de la Cordillera de Talamanca. La pluma de sedimentos del Río Sixaola se extiende varios kilómetros mar afuera, fluyendo hacia el noroeste y afectando los arrecifes coralinos de Punta Mona. Otras áreas del Refugio no están expuestas a tantos sedimentos terrígenos, pero, conforme se altera la región, por deforestación, construcciones, y remoción del bosque riberino y costero, más arrecifes coralinos del Refugio van a ser afectados por sedimentos.

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