The effects of sediments on the bioluminescence of La Parguera Bay, Lajas P.R. and Puerto Mosquito Bay, Vieques P.R.

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Abstract

A comparative study between sediments of La Parguera bioluminescent bay and Puerto Mosquito Bay in Vieques has been conducted from October 2003 to November 2003. The main objective of this research was to examine the differences of sediment composition and size, and temperature. This study was undertaken to understand how factors such as boat traffic may affect sediment deposition and how thas affects the quality and quantity of light in the water column of the bay. No previous research shows how sediments affects these dinoflagellates. But, it is important the study of the differences in the sedimenthology of both bays and how it may affect the life of this organisms. Sediments were collected during 30 days using three sediment tramps in each bay. XRD, sediment composition, sieving and sedigraphs analyses were part of the procedures. Also boat counting, temperature measurements, and light reflectance for both bays were registered from both bays. The study shows that the sediments in Puerto Mosquito, are coarser in comparison to the sediments in La Parguera Bay . Also that the water was warmer in Vieques, wich could be related to sediment suspension in the bay. Boat counting in La Parguera was more than twice in comparison to Vieques.

Introduction

Dense blooms of dinoflagellates with extremely high bioluminescence occur sporadically in warm water around the world. In tropical latitudes, as a result of many topographic and meteorological conditions, certain bioluminescent bays exhibit persistent high concentrations of bioluminescent dinoflagellates (Walker, 1997).

Bioluminescence is a light emission phenomenon created by an organism, in this case a unicellular dinoflagellate, less than 1/500 th of an inch in diameter, called ***Pyridium bahamense*** (figure 1), These spinning flames are actually part animal because they can move around and part plant because they photosynthesize sunlight using chlorophyll. There are several bioluminescent creatures in both bays, but the *Pyridium* is the dominant light producer. Several theories have been developed of why this organisms glow, but it is generally accepted as a type of primitive defense mechanism. They do not really have any control over their luminescence, they simply emit a bright glow whenever they are agitated, or moved around. For a single-celled creature, the brief flash may make them seem larger than they really are and scare away their predator zooplankton. Because dinoflagellates are a type of phytoplankton, they absorb basic chemicals directly from the water they live and this is an important factor in their abundance. This organisms requires specific conditions for its living and reproduction. The tourist exploitation of the places where this organisms live is making a irreversible damage to them.

La Parguera bioluminescent bay located at the southwest coast of Puerto Rico between 17˚58' N and 671 W (figure 2) and has an approximated depth of 4.5 meters in the inner zone and approximately 2.3 meters in the mouth of the bay. Puerto Mosquito bay is located at the south of Vieques between 18˚6 N and 62˚ 26' W (figure 2) and have a depth of 3.9 meters in the inner zone and 1.8 meters at the mouth.

Various scientists have denominated Puerto Mosquito in Vieques and La Parguera Bay in Lajas as the most amazing bioluminescent bays in the world. But La Parguera Bay has shown a decrease in its bioluminescence by approximately 80% in the past years compared with Puerto Mosquito (Walker, 1997).

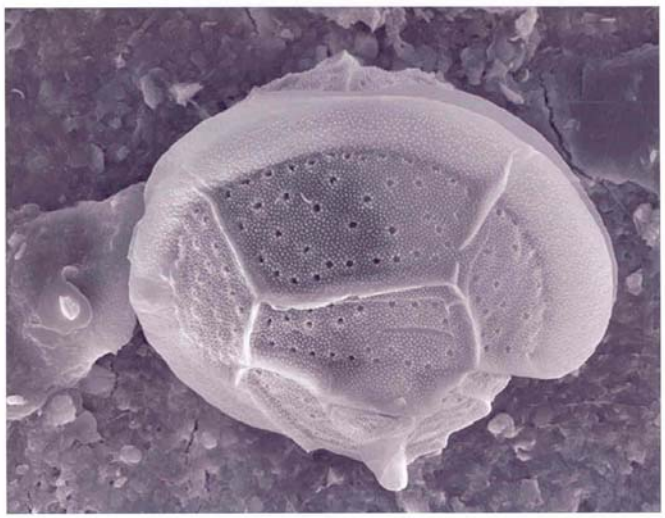


Figure 1

Area of Study

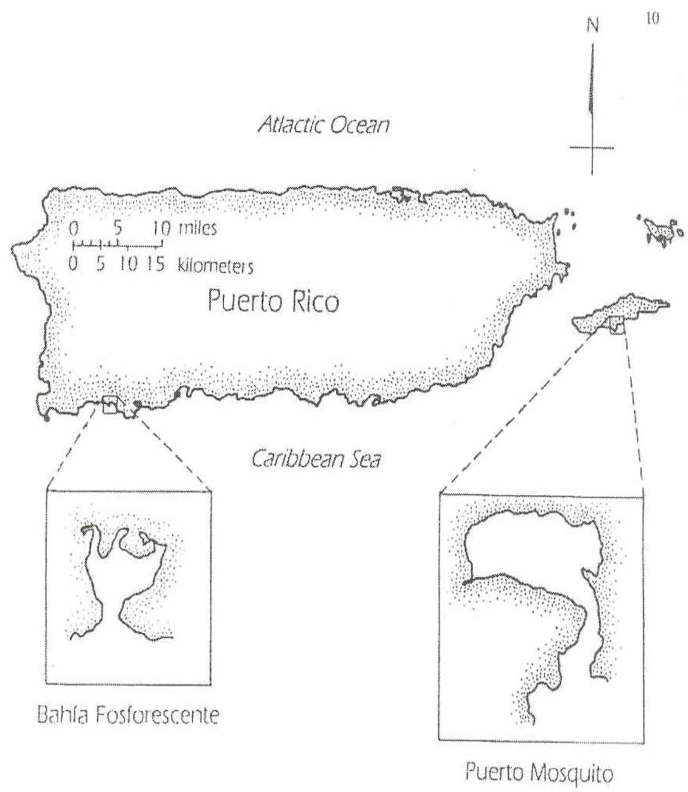


Figure 2

Introduction

A comparative study of these two bioluminescent bays was conducted in 1996 by Alfredo Sanjuan and Juan Gonzalez. The main objective of that research was to determine how boats that enter to La Parguera bay move sediments and how this affects the bay. They found changes in the sediment structures where the upper layers represent an accumulations of finner sediments (particulated organic material) in comparison to the depper ones that present the normal conditions of the bay with coarser sediemts composed mostly of “diatomeas, espiculas”, ostracods, marine algae and mangroove leaves(Sanjuan and Gonzalez, 1996).

Marine sediments can be divided into three categories, based on their composition and mode of origin. Sediment composition provides important information about the origin of individual grains, and energy levels during transport and deposition, especially in areas dominated by clastic sediments of terrigenous(Grains which have been eroded from the land and carried to the marine environment , typically by rivers, wind, glaciers, erosion, slumping, and mass wasting) origins.

Clastic marine sediments can be divided into two broad categories; terrigenous and carbonate. The processes that are responsible for their formation and deposition can be different. Terrigenous sediments are most often of silicate origin(They are composed of quartz, feldspars and other minerals associated with an igneous origin). They are derived from the erosion of upland or coastal areas and transported over considerable distances to their ultimate environment of deposition. Terrigenous sediments can also be eroded carbonate that has been lithified and uplifted. A very clear relationship exist between grain size and energy level, coarser sediments generally reflect higher energy, while quieter areas are dominated by mud. In the marine environment energy level, and therefore, sediment size are controlled by factors such as wave action, exposure, tidal range and water depth. In the other hand carbonate grains are controlled by the skeletal architecture of the organisms from which the organism is derived.

The sorting in carbonate environments can be difficult. The variable grain size and the high porosity of some particles (*Halimeda* or foraminifera with natural pores and chambers) can make the more susceptible to transport than terrigenous sediments. Terrigenous sediments are derived from the breakdown of crystalline igneous rocks. Although sedimentary rocks are eroded to provide grains, their constitutients are generally derived from the prior erosion of igneous or metamorphic rocks. The principal source of terrigenous marine sediments is river discharge. Rivers transport more than 18 x 19^9 metric tons of suspended solids to the worlds oceans annually (Holeman, 1968).

The objective of this research is to measure the impact of sediment movement, caused by different natural and human induced changes in the bays and how they are related to the dinoflagellate population. Suspended sediments affect the amount of light that enters the water column, therefore it is an important factor in the life of these organisms because of the need of light for photosynthesis.

Methodology

Sediment tramps were made with 6 inch wide and 6 inch long *PVC* tubes with a rod of ¾ inches wide and 1 meter long for stabilizing the tramp in the bottom. These tramps were placed at three different places in both bays. Two tramps at La Parguera were lost, or stolen, while one in Vieques was throwed out of the water. The sediments were recollected after a month, and dried up in the laboratory. The weight of each one was calculated by separating the samples of the different tramps into three groups.

The samples for XRD analyses were dried and pulverized and placed in sample holders. XRD analysis is a technique based on differential passage of X radiation through a sample onto a special film. Differences in composition (density) from place to place through the sample cause differences in attenuation. The result and variation in the amount of radiation that reaches the film creates differences in photographic density.

Sieve analysis measures grain diameter by allowing sand to settle through a nest of sieves. Each sieve is a cilinder floored with a wire-mesh screen with squares appertures of fixed dimensions(Prothero and Schwab, 1999). Phi units express grain size as the negative logaritm of grain diameter in millimeters to the base 2. There was used wet sieving after mixing the sample with sodium metaphosphate at 0.5%. This process was used to separate the clay from the sand. The samples were washed and dried for normal dry sieve analysis. Sediments larger than 4 Φ were separate and taken to the sedigraph machine. Sedigraph is an x-ray process that "sieve" sediments > 4 Φ using sodium methaphosphate to separate clay from sand. Sorting was used to express the number of significant size classes in the samples, this may reflect variations in the velocity and the ability of a particular process to transport and deposit (Prothero and Schwab, 1999). Skeweness was measured for knowing the symmetry of the distribution. As the skeweness get coarser it becomes positive.

For sediment compositions, the samples were washed with Clorox until the sample fezzes stops, they were washed, dried and weighted for second time. The lost material was the organic. Then, it is washed with HCl at 10%, this process will take the Carbonates away, the sample was dried and weight again. Everything left were terrigenous materials.

Termometers were placed on each bay, measuring temperature every two hours. The measurements were averaged by time of the day and tables were prepared. Boat counting were made during a weekend with crecent moon in each bay. This was planned this way because full moon in the lowest touristic visiting season due to lower biolouminiscence.

Two measurements were made with the Glowtracka (figure 3), an instrument that stimulates bioluminiscent organisms, in this case the *Pyriduim bahamense,* and then measures the light flashes as the organism passes the detector, but the instrument did not worked properly and after reparation more measurements will be done.

Results and Discussion

Sediment collection in La Parguera were significally higher than the collected in Vieques as shown in table 1, this confirms the results from Sanjuan and Gonzalez in their investigations of 1999. As they suggested, the reason for higher sediment suspension could be due to the tourism exploitation of the ecological place. As shown in figure 4, boat traffic is approximately four times higher than Vieques. The sediments of La Parguera (table 2) show a high composition of terrigenous fine grained sediments(tables 3 and 4), previous works demonstrated that there has been a change in the size and composition of the sediments (Sanjuan and Gonzalez, 1999). There is a layer of fine sediment of terrigenous origin covering the coarser carbonate sediments that shows the previos conditions of the bay (Margalef, 1961). This sediment layer must be the one that boats and ocean currents could and this might be related to changes in the water temperature in the bay and making it colder compared to Vieques as we can see in table 5. These changes in temperature could produce different conditions affecting the dynamics of the dinoflagellates and other organisms.

As we can see in table 6, the sediment composition in the mouth of the Vieques Bay (Vieques mouth refers to Vieques I in the samples and tables) are mostly coarsed grained carbonates (table 7 and 8), that is not easily resuspended. Less boat traffic may also help to keep sediment deposited and and light can warm up the waters (figure 4). The clear waters of this bay allows the growth of organisms that produce carbonate sediments and the living of the *Pyridium bahamense* as previous work demonstrate the higher populations of this organism in this bay (Walker L, 1997).

Inside Vieques bay there are terrigenous sediments as well as finer sediments as we can see in tables 2 and 9. The difference in sediment composition between Vieques bay and La Parguera is just that there is more fine terrigenous sediments in Parguera that is resuspended with boat traffic changing the environmental conditions of the bay.

Sediment recollected in a 30 day period.

Vieques I	24.17g
Vieques II	11.95g
Parguera	43.05g

Table 1

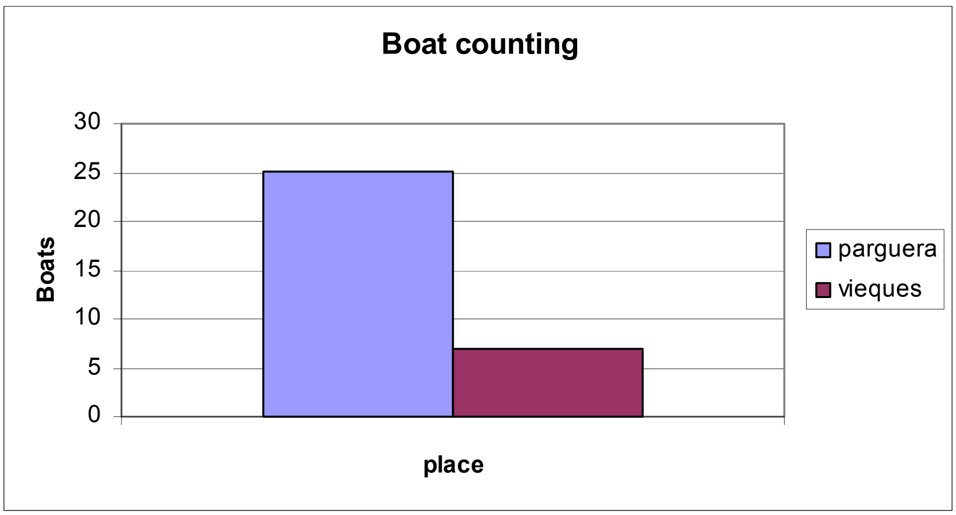
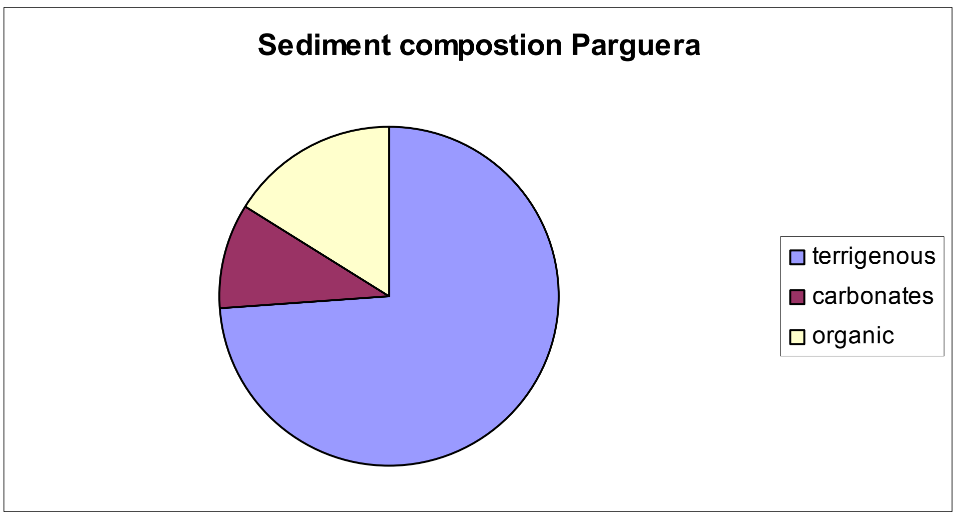


Figure 4



Parguera	
terrigenous	61%
carbonates	23%
organic	16%

Table 2

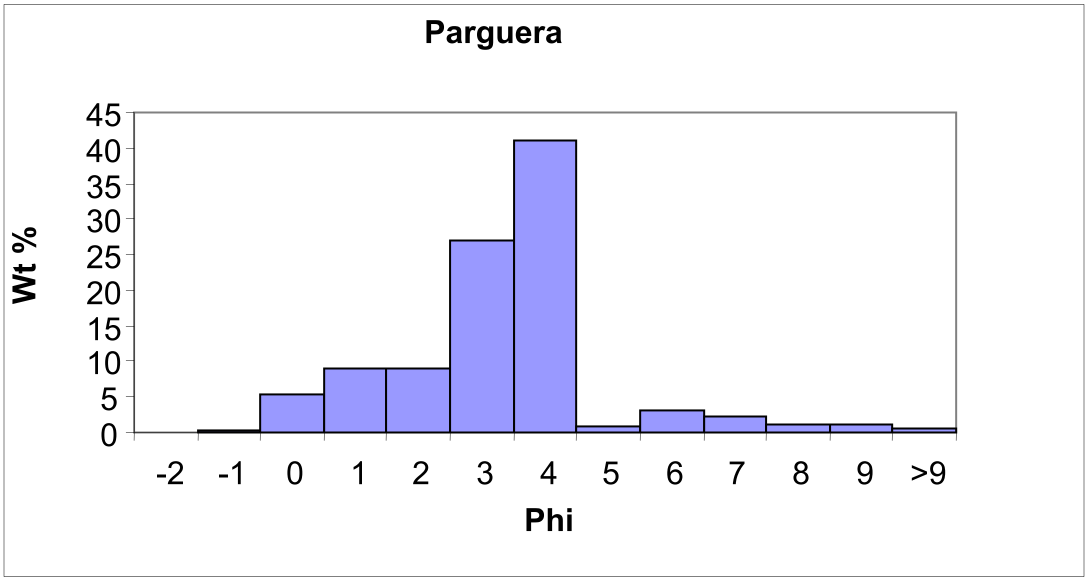


Table 3

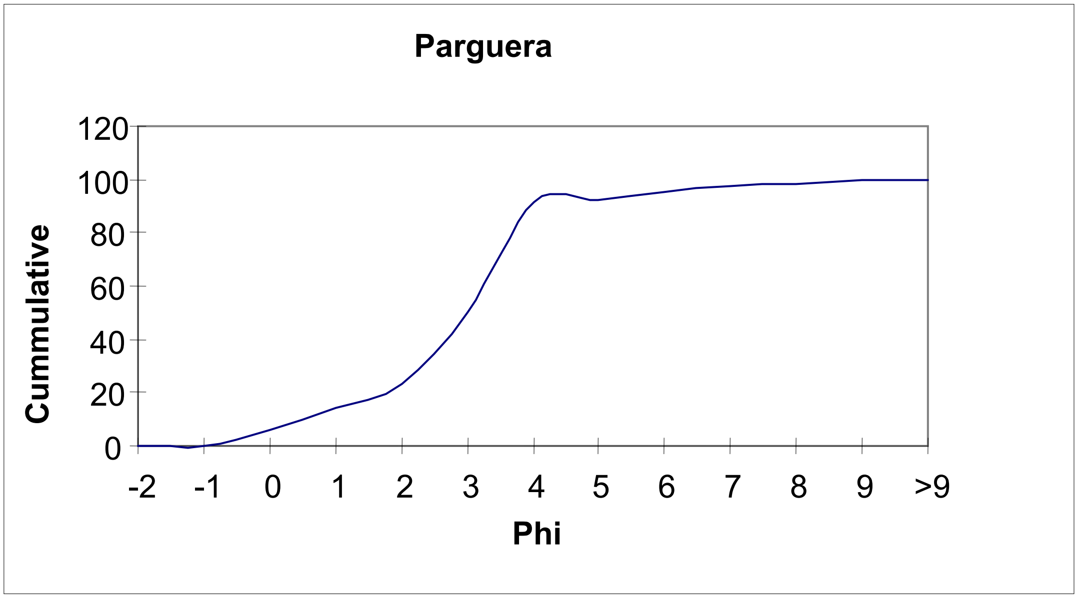


Table 4

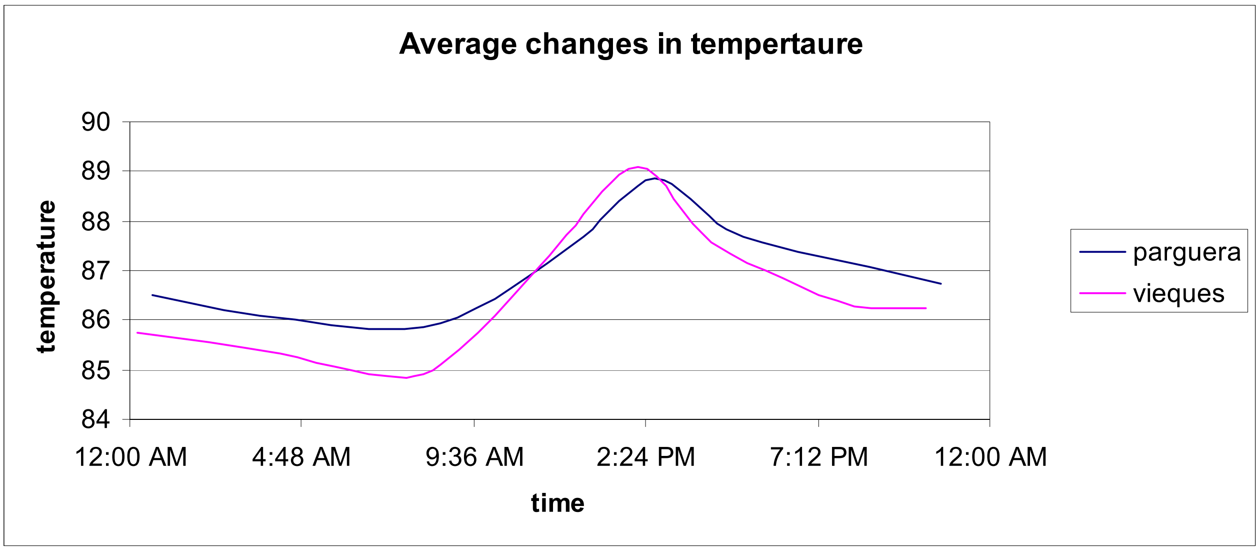
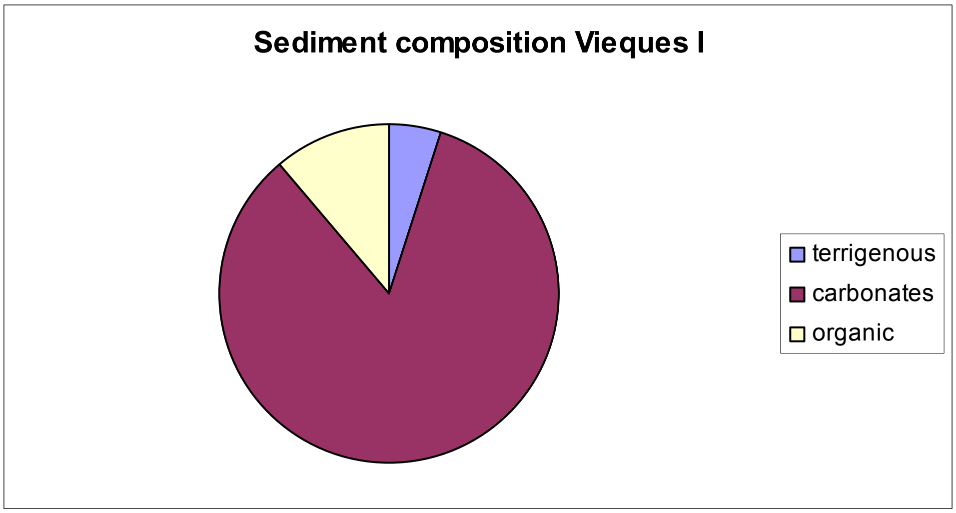

Average changes in tempertaure
90
89
88
87
86
85
84
temperature
12:00 AM
4:48 AM
9:36 AM
2:24 PM
7:12 PM
12:00 AM
time
parguera
vieques

Table 5



Vieques I	
Terrigenous	11%
Carbonates	84%
Organic	5%

Table 6

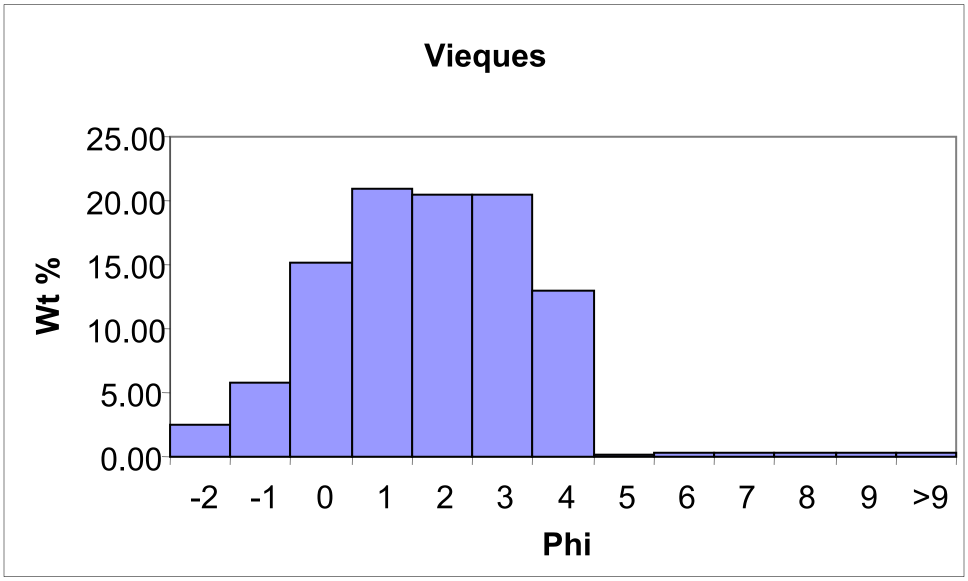


Table 7

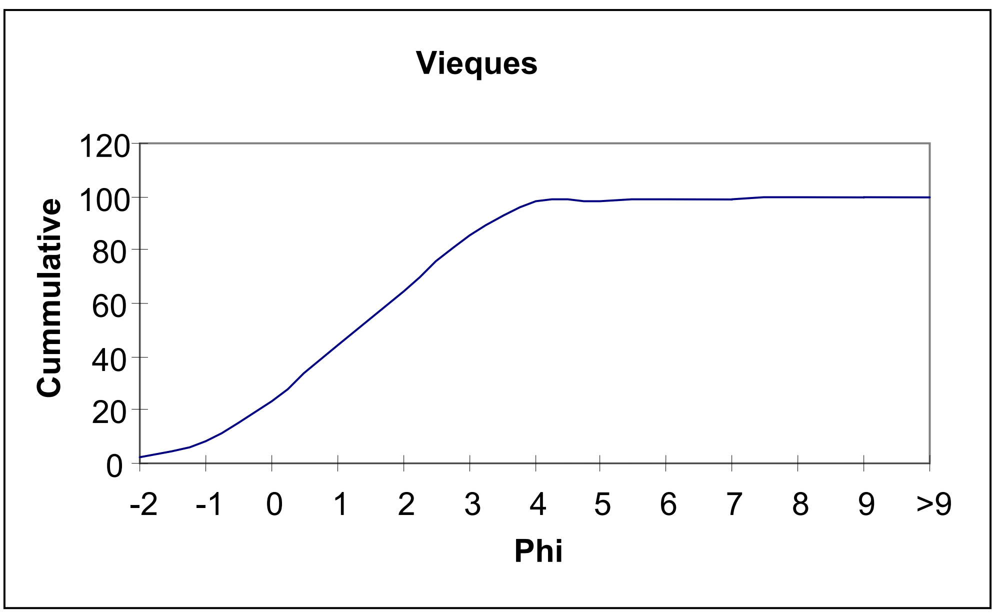


Table 8

Conclusions

The objective of this research was to examine the differences between sediment composition and size as well as temperature changes in both bays. As the results and interpretations demonstrated that there is a difference in sedimentation as well as a difference in sediment suspension between the two bays. Also the positive effect of the tourist exploitation of La Parguera bay was shown.

Other important factors such as erosion from near constructions should be a very interesting part for the continuation of this project as well as the use of the Glowtracka, and monthly measurements of sediments for more that three months. Comparison of the urban impact through the years could be used using remote sensing.

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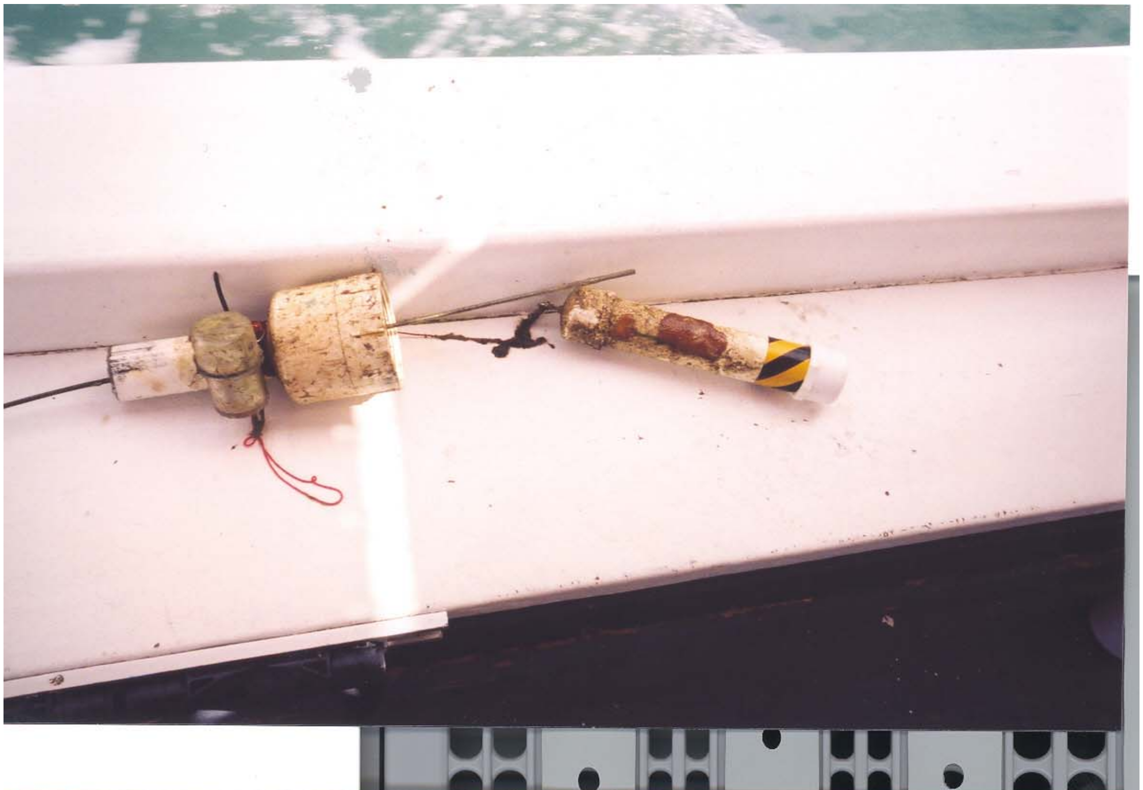
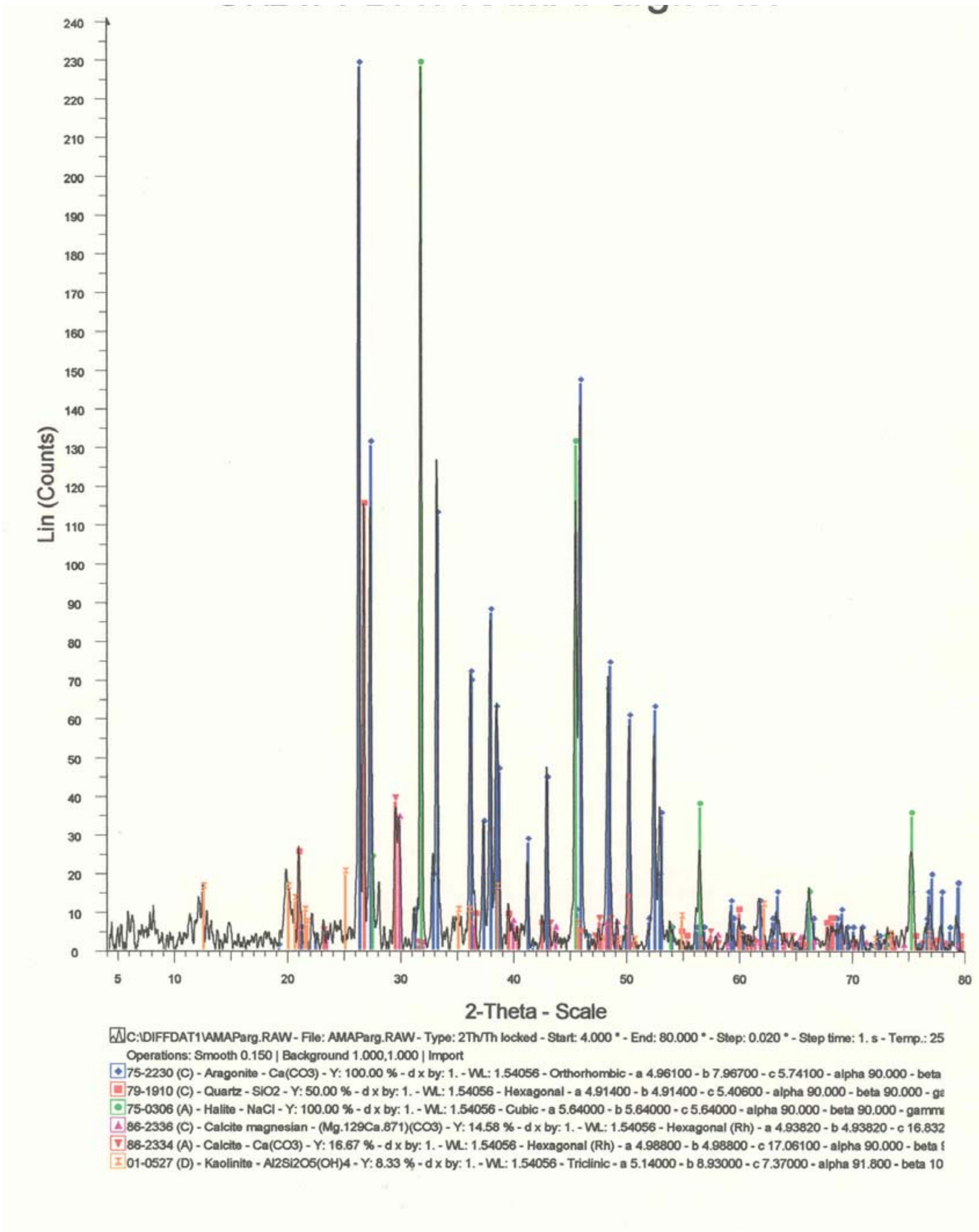
Appendixes

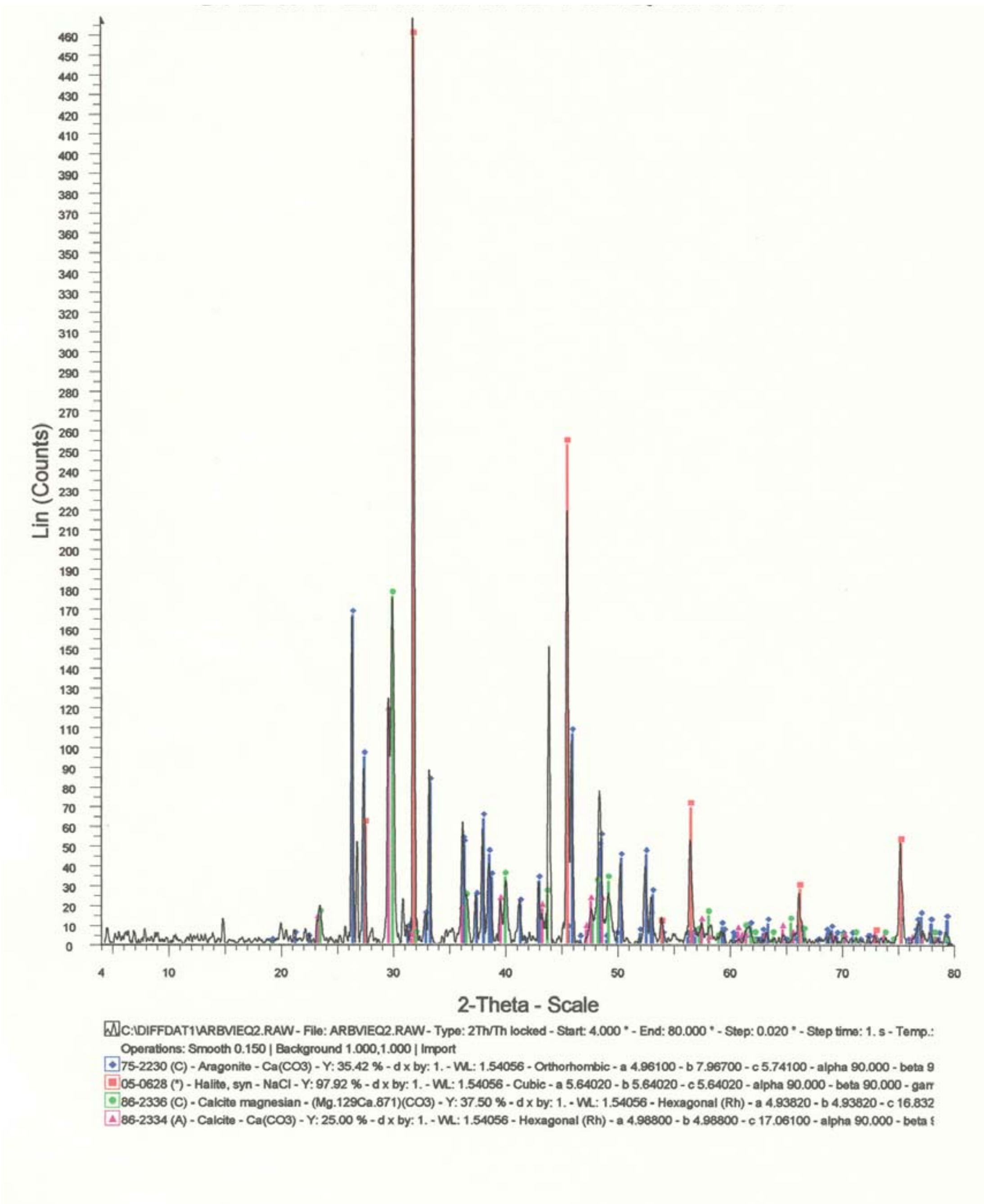


Sediment tramps after recollected.(upper picture)

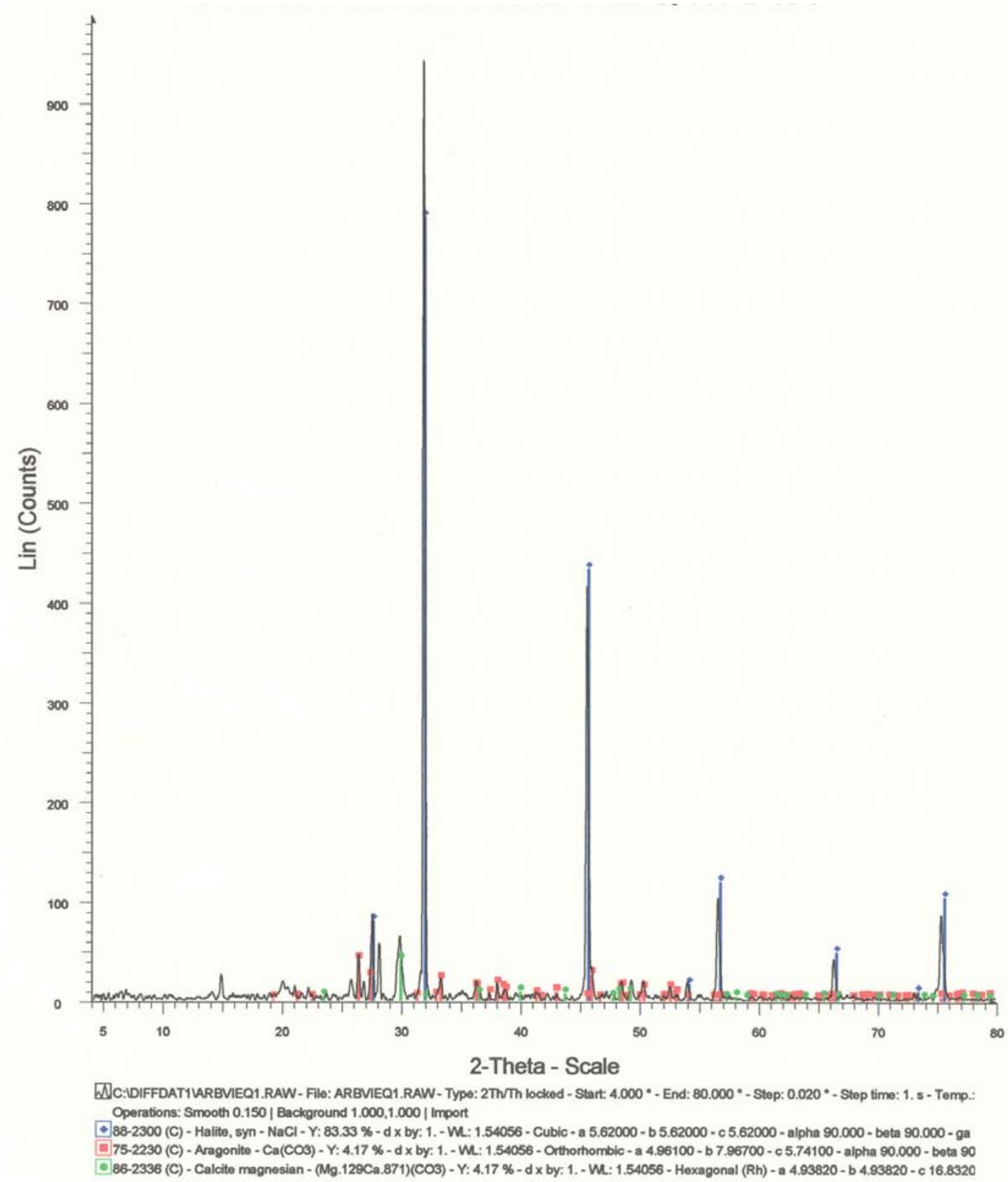
La Parguera Bay mouth.



XRD Parguera



XRD Vieques II



XRD Vieques I

Table 5.3 Formulas for Calculating Statistical Measures Using Phi Unit Values from Probability Plots

I. Measures of central tendency

A. Mean $= \dfrac{\phi 16 + \phi 50 + \phi 84}{3}$

B. Median $= \phi 50$

C. Mode = Midpoint of most abundant class interval on histogram

D. Modal class = Most abundant class interval on histogram

II. Sorting (inclusive graphic standard deviation)

$\dfrac{\phi 84 - \phi 16}{4} + \dfrac{\phi 95 - \phi 5}{6.6}$	$<0.35\phi$	Very well sorted
	0.35ϕ–0.50ϕ	Well sorted
	0.50ϕ–0.71ϕ	Moderately well sorted
	0.71ϕ–1.00ϕ	Moderately sorted
	1.00ϕ–2.00ϕ	Poorly sorted
	$>2.00\phi$	Very poorly sorted

III. Skewness (symmetry) (inclusive graphic skewness)

$\dfrac{\phi 84 + \phi 16 - 2\phi 50}{2(\phi 84 - \phi 16)} + \dfrac{\phi 95 + \phi 5 - 2\phi 50}{2(\phi 95 - \phi 5)}$	$> +0.30$	Strongly fine-skewed
	$+0.30$ to $+0.10$	Fine-skewed
	$+0.10$ to -0.10	Near-symmetrical (unskewed)
	-0.10 to -0.30	Coarse-skewed
	< -0.30	Strongly coarse-skewed

IV. Kurtosis

$\dfrac{\phi 95 - \phi 5}{2.44(\phi 75 - \phi 25)}$	>1.0	Excessively peaked (leptokurtic)
	1.0	Normally peaked (mesokurtic)
	<1.00	Deficiently peaked (platykurtic)

Formulas for Calculating Statistical Measures using phi values