Changes in shoreline and the relation between diversity of shell-mollusks and sand texture on beaches of the West Coast of Puerto Rico

By

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Abstract

The effects of shoreline changes on coastal habitats, such as loss of faunal biodiversity, remain as central topics of marine ecological research. Thus, we determined shoreline changes (erosion or deposition) at selected beaches based on aerial photographs and using ENVI Remote sensing program. It is known that the distribution of marine invertebrates in the beaches is partly directed by the composition of the substrates; however, relationships between sand texture and mollusk diversity had not been assessed yet in the beaches of Puerto Rico. Therefore, we set transects on two occasions in four beaches on the western coast of Puerto Rico: Balneario Tres Hermanos (Añasco), Córcega (Rincón), El Combate (Cabo Rojo) and El Maní (Mayagüez), to determine patterns of abundance and species richness of shell-mollusks. Our hypothesis was that the patterns of abundance and species richness for gastropods and bivalves (death or alive species; since based on collected shells) varied significantly among the selected beaches, and mollusk diversity was somehow related to sand textural attributes, such as sorting and particle grain size. A total of 133 taxa were collected and identified, at least to family-level. These organisms comprised 56 and 83 species of bivalves and 30 families and 50 species of gastropods. Every locality showed a distinctive mollusk fauna. The bivalve *Donax denticulatus* was found at all selected beaches and in both samplings. Gastropod *Echinolittorina ziczac* found only at Córcega, Rincón, and El Maní, Mayagüez, where it exhibited aggregated spatial dispersion. ANOVA and Tukey tests indicated that significant differences in mollusk diversity (richness and abundance) between beaches were related to the following factors: the number of transects, the study site (beach *per se*), zones (sand versus aquatic), and samplings (I, II). Changes in the Shannon Wiener Index values suggested changes in diversity at these beaches over a short period of time (between both samplings). According to Jaccard Index values, the species compositions in the samples from differente beaches had low similarities among them. A granulometric analysis showed that the sands of the selected beaches ranged from fine to coarse, with coarse sands dominating during both samplings. In general, PCA analyses showed that increased sorting of the sand was not associated to diversity of mollusks. This study will serve as a baseline for future studies on the monitoring and conservation of biodiversity of shell-mollusks found at the Caribbean sandy beaches.

Resumen

Los efectos de los cambios costeros en los hábitats marinos, como la pérdida de la biodiversidad de la fauna, siguen siendo temas centrales de la investigación ecológica marina. Por lo tanto, determinamos los cambios en la línea costera (erosión o deposición) en playas seleccionadas en base a fotografías aéreas y utilizando el programa de detección remota ENVI. Es conocido que la distribución de los invertebrados marinos en las playas está dirigida en parte por la composición de los sustratos; sin embargo, las relaciones entre la composición de arena y la diversidad de moluscos aún no se habían evaluado en las playas de Puerto Rico. Por lo tanto, establecimos transectos en dos ocasiones en cuatro playas seleccionadas en la costa occidental de Puerto Rico: Balneario Tres Hermanos (Añasco), Córcega (Rincón), El Combate (Cabo Rojo) y El Maní (Mayagüez), para determinar patrones de abundancia y riqueza de especies de moluscos con concha. Nuestra hipótesis fue que los patrones de abundancia y riqueza de especies de gasterópodos y bivalvos (especies basadas en las conchas recolectadas) variaron significativamente entre las playas seleccionadas, y que la diversidad de moluscos está de alguna manera correlacionada con los atributos de la textura de la arena, tales como sorteo y tamaño de grano. Se recolectó e identificó un total de 133 taxones, al menos a nivel de familia. Estos organismos comprendían 56 y 83 especies de bivalvos y 30 familias y 50 especies de gasterópodos. Cada localidad mostró una fauna distintiva de moluscos. El bivalvo *Donax denticulatus* se encontró en todas las playas seleccionadas y en ambos muestreos. Por otro lado, el gasterópodo *Echinolittorina ziczac* fue encontrado únicamente en Córcega, Rincón, y El Maní, Mayagüez, donde mostró una dispersión espacial tipo agregada. Las pruebas ANOVA y Tukey indicaron diferencias significativas en la diversidad de moluscos (riqueza y abundancia) entre las playas, que se relacionaron con los siguientes factores: el número de transectos, el sitio de estudio (playa *per se*), zonas (arena versus acuática) y muestreos (I, II). Los cambios en los valores del Índice Shannon Wiener sugirieron cambios en la diversidad en estas playas en un corto período de tiempo (entre ambos muestreos). Según el índice de Jaccard, la mayoría de las muestras tenían una similitud baja entre ellas, en los referentes a composición de especies. Un análisis granulométrico mostró que las arenas de las playas seleccionadas variaban de arenas finas a gruesas, con dominio de arenas gruesas en ambos muestreos. En general, los análisis de Componentes Principales mostraron que el sorteo de la arena no tiene relación con la diversidad de los moluscos. Este estudio servirá como una línea de base para futuros estudios sobre el monitoreo y la conservación de la biodiversidad de los moluscos encontrados en las playas de arena del Caribe.

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Dedication

To my parents, Maribel Molina Rivera and José L. Colón Rodríguez, and my grandmothers:
Deadina Rivera Rodríguez and Caridad Rodríguez Maldonado

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Introduction

Many coastal habitats in Puerto Rico and other parts of the world have been severely affected by shoreline changes. The shoreline zone is an area where the sea and land join that plays a very important role in integrating the sea with its watershed (Cepeda and Jiménez, 2003). Two critical environmental problems of coastal zones are erosion and the loss of biodiversity. The problem of coastal erosion is recognized worldwide (Laborde, 2010). Erosion is mainly the loss or displacement of sand caused by wind, waves and currents. It can be exhacerbated by the absence of submarine sand deposits near the shore. Erosion increases with tropical storms and is affected by local wave regimes, flood events of all magnitudes and frequencies, and the presence of submarine canyons (Morelock, 2005). Most marine sediments are derived from terrestrial erosion and the disintegration of marine organisms (Barreto, 1997). Therefore, erosion responds to both natural (climate change and increase of sea level) and anthropogenic factors.

Waves and currents have marked effects in the transport of sediments. Because of these phenomena, there is a loss of inter-tidal habitats and a change in the content of organic matter and other sources of food for many species. The intense turbulence generated by breaking waves leads to the sediment-transport and provides the impetus for the movement of fine sands (Jiang et al. 2015). These shoreline changes will affect species biodiversity and abundance on the intertidal zone, including the many species of mollusks that inhabit this area.

The grain size and sorting are textural parameters of modern sediments and constitute important aids to infer analogous ancient sedimentary environments. At some locations pebble and rock beaches are adjacent to sandy beaches and on sandy beaches variations in ‘‘sediment’’ composition along and across the beach: fine and coarse sands and concentrations of shells. These observations indicate that transport processes depend on size, density, shape and roundness of grains. Basically, the cross-shore grain size distribution depends on the composition of various sediment sources and the energy level of the wind wave forces in an environment and the tides in tidal environments.

Sediments can structure benthic communities because of grain size preferences by various organisms. Also, sediments may have biological origins in the skeletal material of corals, macroalgae, phytoplankton, foraminifera, radiolarians, mollusks, among others. Sediments can provide information about source materials, the depositional environment (amount of energy there is in waves and currents), and other physical and chemical factors.

Coastal sediment is made up of weathered terrigenous rock for the most part, plus organic detritus, plants, worms, sea shells (if marine), and pore spaces. Quartz grains in most cases are the dominant grain type in sediments, but there could also be rock fragments. When rocks are broken down into fragments, either through the mechanical means of weathering, or through chemical reactions, the fragments become part of the sediments. When that sediment is compacted or cemented together, it forms a sedimentary rock. Sediments are either clastic or chemical; that is, rocks are broken down through either mechanical or chemical means (Folk, 1980).

One way to characterize sediments is by determining the sizes or texture of the grains. Texture refers to the properties of any particular sediment, such as particle size, shape, roundness, and sorting. To characterize the size of the sediments, a representative sample of the sediment is run through a set of sieves to break the sample into subsets or size classes and statistics are employed to reconstruct the characteristics of the size classes. A well-sorted sediment is one in which the grains are all about the same size. In contrast, poorly-sorted sediment contains a chaotic mixture and large, intermediate and small grains. Shape is a measure of the sphericity of a grain. Some grains are almost spherical, whereas others may be elongate or flattened. Particle roundness refers to the smoothness of a grain, regardless of its shape. Grains may be rounded, subangular or angular.

Rocky shores are important because they provide habitats for a wide diversity of organisms while they also serve as nursery areas for many fish and crustacean species. These areas also provide shelter for organisms by reducing the power of waves, algal beds can be an important food sources for rare and threatened species (like sea turtles), and they also help stabilize inshore sediments. In the low tide zone, organisms are covered by seawater most of the time and are exposed to air only at the lowest of tides.

Sandy beaches are large ecosystems that are known by their geomorphology/ sedimentology and their interactions with erosive and depositional forces. They also provide habitat for not only hundreds of plant and animal species, most being small and buried within the sand, and are important nesting habitats for sea turtles (McLachlan and Brown, 2006). The vulnerability of the beach habitat is largely dependent on the rates of sea-level rise, coastal erosion, and the frequency of extreme events (Voice et al., 2006).

Mollusks are conspicuous inhabitants of coastal ecosystems. They constitute the second largest animal phylum, after the Arthropoda, regarding the total number of described species. Mollusks feed on a wide variety of food sources and exhibit a wide range of trophic modes. Mollusks are classified into eight major classes of which the most important are: Gastropoda, Bivalvia, Scaphopoda, Polyplacophora and Cephalopoda.

Gastropoda is the largest taxa within Mollusca as more than 60,000 species have been described worldwide. In Puerto Rico, about 1,000 species of gastropods (snails and slugs) have been described, of which over 803 are marine (Ortiz-Corps, 1998; García-Ríos et al., 2008). Snails are usually more concentrated from mid to low water mark in the shallow intertidal and sub-tidal zones (Mohammad, 2008); however, these mollusks are distributed from the intertidal zone all the way to the abyssal zone, and there are also free-swimming and pelagic species (Torreblanca-Ramírez et al., 2014). Gastropods are widely distributed and have received greater scientific attention in several places. Among many places, there are comprehensive works for the Archipelago of the Azores in the Northeast Atlantic (Cordeiro et al., 2015) and all the way to other places of Europe (Mclean 1967; Ciampalini et al., 2014; Giannelli, 2014), South America (Flores-Rodríguez et al., 2014; Arruda and Amaral, 2003; Creed and Kinupp, 2011) and the Caribbean (Bovbjerg, 1984), resulting in a steady increase in the knowledge of their biodiversity. Gastropods have been adaptively successful in marine environments, where they are important elements in the biological equilibrium of many ecosystems and habitats. Their trophic habits are very varied, as they can be carnivorous, herbivorous and suspension feeders. Therefore, they act as ecological regulators and bio-indicators (Baqueiro et al., 2007).

The macrofauna of high-energy sandy beaches tends to be dominated by filter feeders and carnivorous invertebrates. Brown et al. (1989), in their study in South African beaches, showed that the bivalve *Donax serra* and the gastropod *Buttia digitalis* are found at sandy beaches, where both species face the same conditions, such as an unstable substratum, a harsh environment, and tidal migration. Also, both species are very successful and achieve high densities on beaches exploited by humans. At least during low tides, they can display some vertical separation in the sand column, in which *Buttia* becomes a much shallower burrower than

Donax, but, unlike *Donax*, it emerges regularly from the sand in search of food. Gastropods are frequent inhabitants of sandy shores in tropical and subtropical regions of the world (Soares et al. 2003). Monteiro and Bemvenuti (2006), in their work on the status of knowledge about sandy beach macrofauna zonation pattern, concluded that the distribution of characteristic taxa across shores assumes the form of three distinct and universal zones: supralittoral, littoral and sublittoral. Gastropods inhabiting subtidal soft-bottoms have a great influence on the populations of other benthic animal. Moreira et al. (2010) showed that intra-annual seasonality in faunistic attributes of the assemblage (e.g., composition, abundance, diversity) is related to patterns of recruitment and seasonal variations in food supply. Factors that could affect the marine invertebrates, such as the gastropods, in sandy beaches are the rise and fall of the tides, and wave action; if organisms are not well-attached to the substratum, they are in the risk being carried away by the currents or cast upon the beach and suffocate and die.

Neritidae, or the nerites, is a family of mainly tropical and subtropical gastropods. The intertidal zonation patterns of these organisms are mainly related to their evaporative cooling abilities (Lewis, 1960). The tessellated or checkered nerite (*Nerita tessellata*) is an intertidal gastropod that is one of the smallest nerites in the eastern Atlantic and is found along subtropical and tropical marine coasts from Florida to Texas and through the Caribbean to Brazil (Giovas et al., 2013). Like in other nerites, it resorbs the posterior portions of its shell, enlarging the interior chamber from within to accommodate its growing ample visceral mass (Vermeij, 1987). Giovas et al. (2013), in their study at Coconut Walk site on the Caribbean island of Nevis, determined that *N. peloronta*, *N. versicolor*, and *N. tessellata* locally distributed within the high, medium, and low intertidal zone, maintaining their relative position by migrating during the tidal cycle.

Bivalvia is the second most diverse class of Mollusca with over 9,000 described species. In Puerto Rico, Ortiz-Corps, (1998) reported 274 marine species. Many bivalve species play important roles in aquatic ecosystems by filtering the water and serving as habitat and prey for a variety of marine organisms. Bivalves usually have limited or no movement, leading to a sedentary or sessile life. They are adapted to feed on small, suspended organisms and organic particles or deposits (Flores-Rodríguez, 2004). Also, bivalves are good biological indicators in the detection of changes in sand grain-size in beaches (La Valle et al., 2011).

Clams genus *Donax* are widespread on the exposed sandy beaches of tropical and temperate coasts (Ansell, 1983). Members of the family Donacidae are characterized by their moderately large pallial sinus and the tightly-close valves (Keen, 1971). In the wider Caribbean region, two species, *Donax denticulatus* and *D. striatus*, occur on sandy beaches. Both species have similar distribution range in a same beach and they are more common in the swash zone (Wade, 1967).

Some bivalve species, such as *Donax denticulatus*, are indicator species for the status of sandy beach-ocean front habitats. They live in the upper surface of the intertidal zone. Receding waves usually expose the clams, which then vigorously bury themselves back into the sand. The organisms that live in the intertidal zone have adaptations to bury quickly. For marine organisms, the fine sands tend to be more appropriate to bury. Many of the other animals that are buried in the sands lack the strength or capacity to do so in coarse sand (Texas Parks and Wildlife Department, 2012-2015).

Since many snails feed by scraping hard surfaces with their radula and bivalves are mostly filter-feeders, we predict that there should be correlations of particle grain size composition with the biodiversity of shell-mollusks in the selected beaches.

Relevance and Precautions

Intertidal mollusks are good experimental organisms for scientific research. The intertidal zone is intermittently covered by water and high tides bring nutrients and food. When the tide retreats, waste products, eggs and larvae are taken away. Therefore, organisms that live in this area must be adapted to the high-energy of this zone. Knowledge of species distribution is important in understanding how environmental factors influence population dynamics and loss of diversity. The present study pretended to provide a more complete understanding of the abundance and diversity of gastropod and bivalve populations found in four selected local beaches.

Also, the present study examined aspects of the distribution of gastropods and bivalves species that appear to be limited to one or a few locations (Warmke and Tucker, 1975). Some species that are found on the beaches and that can survive wave-dashed sand are members of *Donax*, as well as snail species in the genera *Terebra*, *Olivella*, *Polinices* (Warmke and Tucker, 1975). The biodiversity of shell-mollusks in the Caribbean is still poorly known, but previous research in other geographical areas such as South America, North America, Europe, and Asia suggests there is a high biodiversity in many parts of the world.

Some of the beaches in which we conducted this research are sea turtle nesting grounds. The species of sea turtles that use this area for nesting are: Leatherback (*Dermochelys coriacea*), Hawksbill (*Eretmochelys imbricata*) and Green sea turtles (*Chelonia mydas*). Leatherback nesting usually starts in March and ends approximately at the end of the summer during the month of July, while hawksbill nesting usually runs from August to October, and Green turtle nesting goes on from June to September. All sea turtles are endangered species and are protected by State and Federal laws. The Center for Coastal Conservation and Ecological Restoration

(Vida Marina; UPR-Aguadilla) works on monitoring the nesting activity and tagging these turtles in the study area. We communicated with their staff to know the specific dates of turtle's nesting of these beaches and avoided taking sediment samples near sea turtle nesting areas. Visiting the beaches was coordinated with Vida Marina to avoid damage to these species. Our samplings were widespread and very focal within a single beach and every exact site was not sampled more than twice. The depth of sampling was within 10 cm of the surface and the volume of sand removed was relatively small (ca. 100g). Rocky shores were studied with quadrants, without removing the mollusks.

Objectives

1. Determine patterns of abundance and species richness of both gastropods and bivalves (dead and alive; as determined by focusing on shells), within transects in four selected beaches on the western coast of Puerto Rico: Balneario Tres Hermanos (Añasco), Córcega (Rincón), El Combate (Cabo Rojo) and El Maní (Mayagüez).

2. Correlate species richness with sand texture in the four selected beaches.

3. Determine shoreline changes (erosion or deposition) at selected beaches based on aerial photographs and using ENVI Remote sensing program.

Hypotheses

The distribution of marine invertebrates on the beaches is directed partly by the factor of tidal exposure and by the composition of the substrate. Long-term changes in tidal exposure are reflected in the composition of the substrate and increases in sand particle size results in a change in beach slate and a predicted decrease in species richness and abundance (Wieser, 1959). In preliminary data from Balneario Tres Hermanos, Añasco, sand composition and mollusk diversities were similar among different transects. However, differences in sand texture and mollusk diversity between this and other beaches had not been assessed yet.

Hypothesis 1: Given the fact that our preliminary studies in Añasco beach did not reflect significant differences in mollusk abundances in samples from different points along the shore, we predict that patterns of abundance and species richness of both gastropods and bivalves (death or alive species) will not be significantly different among transects of the same beach.

Hypothesis 2: Given the fact that literature shows that beach mollusks have preferences for sediment types specially particle grain size, we predict that there will be significant negative correlations between the mean values of particle grain size the species composition of the bivalve mollusks.

Hypothesis 3: Given the fact that literature shows that beach mollusks have preference for sorting sediment, we predict that there will be significant positive correlations between the mean sorting and the species composition of the mollusks.

Literature Review

Beaches in Puerto Rico

Beaches are a natural resource of great ecological, educational, social, economic and cultural value (Bush et al. 1995). They are the natural resource most used for outdoor recreation (Laborde, 2010). They also provide habitats to a variety of species of plants and animals and serve as nesting area for endangered species such as sea turtles.

Beaches are accumulations of sand or gravel that extend from low tides to the uppermost extent of wave impact (Morelock, 1978). They are very dynamic systems with physical space of interaction between waves, tides and winds that loose sediments (Caravaca-Colina et al., 2015). All beaches are different in their geographic extension, wave regime, and in the color and texture of their sands (García, 2005). Beaches are constantly changing in shape and appearance. The coastal zone of Puerto Rico is remarkably diverse, and some important sandy beaches are Balneario Tres Hermanos (Añasco), El Maní, (Mayagüez), El Combate and Playita Rosada (Cabo Rojo), and Balneario de Rincón (Rincón), among others (García, 2005).

Shell-mollusks

The diversity of organisms inhabiting sandy beaches is determined by physical parameters such as waves, tides, slope of the beach, and the size of the sediments (Defeo and McLachlan, 2005). Although the scientific literature on beach organisms such as marine mollusks is abundant, the ecology of sandy beaches remains a subject that has received little attention, especially in the Antilles (Bush, 1966; González-Liboy, 1971; Sastre 1984; 1985;

Juanes, 1996; Ortiz-Corps, 1998; McLachlan and Dorvlo, 2005; Diez and Reyes, 2014; Ocaña et al., 2015).

Mollusks comprise the second most diverse animal phylum that exists today; and this fact holds true for Puerto Rico too (Joglar et al., 2014). As stated by Manikurve et al. (2004), mollusks are highly successful invertebrates in terms of ecology and adaptation and are found nearly in all habits ranging from deepest ocean trenches to intertidal zones and from freshwater to land, occupying a wide range of habitats.

Much of the molluscan diversity occurs in the tropical world, but despite this great diversity very few studies on mollusks have been carried out in the tropics (Emberton, 1996). They are found in different habitats such as mangroves, coral reef, rocky coasts, sandy beaches, sea grass beds and at greater depth in the sea. They are more diverse and abundant in the rocky intertidal zone along the coast, sandy stones, intertidal flats and mangrove areas (Ramkrishna and Dey, 2010).

The Caribbean, including the Antilles, contains the greatest concentration of marine species in the Atlantic Ocean. Lists of species are the most elementary data in ecology, biogeography, and conservation biology. They are mostly used to determine the number of species occurring in each area, but they can also be employed to determine distribution patterns, for the identification of biodiversity ‘‘hot spots’’, or for designing conservation strategies (Miloslavich et al. 2010). This information is also very important as baseline data to determine the effects of climate change and other factors on an environment. Gastropods and bivalves are generally benthic organisms that are regularly used as bio-indicators of aquatic health (Vanmali and Jadhav, 2015). However, the use and comparability of species inventories are limited by the extent of their completeness and the heterogeneity of sampling effort between sites or areas (Mora et al., 2008).

A total of 12,046 marine species of mollusks have been reported for the Caribbean region. Among the Mollusca, the gastropods appear to be more diverse (more than 750 species) in Cuba, the Lesser Antilles, and Colombia. Meanwhile, bivalves exhibit a similar trend but seem by far more diverse in Puerto Rico (308 species) than in the Lesser Antilles. In general, mollusk species richness seems to be highest (more than 1,000 species) in Cuba, Colombia, the Lesser Antilles, and Puerto Rico. Monitoring and biodiversity assessments will agree to better understand diversity patterns and improve the effectiveness of management strategies for marine ecosystems (Miloslavich et al., 2010).

Other relevant works

Shoreline changes in the sandy beaches are caused by the influence of the underlying geology in the near shore, interactions between the bathymetry and physical oceanographic processes (such as waves and currents), increase of sea level, hard stabilization along the coast, and sand-management practices that allow removal of sand from the coastal system (Thieler et al., n.d. 2016). These changes undoubtedly have repercussions on the biota.

Many of the projects focusing on marine invertebrate associated to beaches have been based on the abundance and biodiversity of phyla such as: Crustacea (Dahl, 1952; Gonzalez-Liboy, 1971), Insecta (Paredes et al., 2007), Tubellaria (Bush 1966), and shell-mollusks (Gonzalez-Liboy; 1971, Ansell, 1972; Sastre, 1984, 1985; Esqueda et al., 2000; Gaspar et al., 2002; Flores, 2004; Baqueiro et al., 2007; Ocaña et al., 2013; Caravaca-Colina et al., 2015). Studies that have been done in the Caribbean recognize the pioneering work by González-Liboy

(1971) and Sastre (1984, 1985) because they were among the first to study the biodiversity and distribution of shell-mollusks in sandy beaches by employing a standardized methodology.

The ecological literature on sandy beaches can be divided into main groups according to the region of the study sites: like studies in Europe (Dahl, 1952; Gaspar et al., 2002; Kosyan et al., 2012), North America (Bush, 1966; Dexter, 1969; Keen, and McLean, 1971; Adamkewicz and Harasewych, 1996), Asia (such as India) (Ansell et al., 1972; Poulami et al., 2014; Vanmali, 2015), South America (Esqueda et al., 2000; Flores, 2004; Paredes et al., 2007; Aldea and Rosenfeld, 2011; Castillo-Rodríguez, 2014; Torreblanca-Ramírez et al., 2014), and the Caribbean (González-Liboy, 1971, Sastre 1984,1985, Ocaña et al., 2013, Caravaca-Colina et al., 2015).

According to Bouchet et al. (2002), studies on molluscan species richness have been ignored in ecological studies because of an insufficient coverage of the spatial heterogeneity and sampling effort. This is particularly important in the case of bivalves because they possess diverse life history stages, and a same species could be found in many habitats, which require specialized sampling techniques. Gastropods are very important for their economic, commercial and cultural significance (Wye, 1991; Díaz and Puyana, 1994), as well as their ecological role in regulating marine populations (Aguilera and Navarete, 2007; Guerry et al., 2009). Thus, special consideration should be given to the complexity of the environment and to sampling techniques to obtain a better understanding of the structure of the species assemblages (Esqueda-González et al., 2014).

In the literature about sampling methods, most of the authors have suggested that sampling techniques are designed to work during low tide, with either 3 to 5 (González-Liboy, 1971; Ansell et al., 1972, Sastre 1984, 1985; Esqueda et al., 2000; Gaspar et al., 2002; Ocaña et al., 2012; Ocaña et al., 2013; Ocaña et al., 2015), 3 to 6 (Caravaca-Colina et al., 2015) or 1 to 8 (González-Liboy, 1971; Kosyan et al., 2012) perpendicular transects. Meanwhile, authors have excavated at depths of 10 cm (Sastre, 1985), 15 cm (Raffaelli et al., 1991), 20 cm (Ocaña et al., 2013) and 0.5m and 6.0 m (Gaspar et al., 2002), finding a decrease in the number of smaller individuals and an increase in the number of larger individuals with increasing depth (Paredes et al., 2007; La Valle et al., 2011). The reason to monitor during low tide is to be able to mark the organisms, prevent interference between low-high tides (Ansell, 2001), and because individuals can migrate to the lower part of the intertidal zone where they are capable to withstand the onslaught of waves due to their greater burial capacity (Ocaña et al., 2013).

La Valle et al. (2011) aimed to investigate the relationship between the distribution and population densities of *Donax trunculus* and sediment grain sizes, in order to use this species as a biological indicator of beach grain-size variations. They did massive samplings during several months (about 1.8 million cubic meters of sands) at six sites along the Latium coast in the Central Trryhenian Sea, Italy. They used the Udden-Wentworth grain-size classification scale for standard parameters (i.e., mean, sorting, kurtosis and skewness), and Principal Component Analysis (PCA) and Canonical Discriminant Analysis (CDA) to test the statistical correlations between clam densities and sediment grain size classes. *Donax trunculus* densities showed a significant positive correlation with grain size and a negative correlation with coarse sandy sediments.

Nel et al. (2001) investigated the effect of grain size on the burrowing performance of two bivalve species: *Donax serra* and *D. sordidus*. Both species were collected from Maitlands River beach (St. Francis Bay, South Africa). Sands were obtained from a series of beaches and these sediments were sorted into nine different grades of coarseness from very fine (90 µm) to very coarse sand (2000 μm). A significant and positive relationship ($p < 0.05$) was found between shell length and burial time in all sand grain sizes. The burrowing performance of *D. serra* was faster in the fine and medium sands, while the performance for *D. sordidus* changed with changes in sediment particle size. They also concluded that grain size and the concurrent change in swash climate interact to exclude both bivalve species from coarse-grained intermediate beaches.

Hunt (2003) explored the relationship between sediment transport and bivalve dispersal. Experiments were conducted in a racetrack flume to examine the effect of grain size, flow and clam size on rates of erosion of the juveniles of two clam species: *Mya arenaria* and *Mercenaria mercenaria*. Physical characteristics of clams and sediment were measured to predict initiation of motion of transport. Also, the erosion of the juveniles was examined at two shear velocities and sediment grain size of 179 μm. They concluded that shear velocity, sediment grain size, clam species and clam size were all factors affecting erosion and transport of juveniles. They also demonstrated that the erosion of the sediment and the associated biological community will depend on a variety of factors, including boundary shear stress and physical characteristics on the sediment.

González-Liboy (1971) deployed eight beach transects (1m wide), from backshore to beyond the breaker zone, to define zonation patterns. Sastre (1984) laid randomly three different transect lines through the wash coastlines by 10 m apart and used $0.25m^2$ quadrants with an anchoring device placed along transects. Additionally, Sastre (1984) extracted two shovelfuls of sand in a way to remove top layer of the sand in each quadrat. Frequently used tools for field work include a corer which consists of a heavy plastic tube with an internal diameter of 3.5cm and a length of 50 cm (Bush, 1966), shovel and sieves (animals in swash zone and below), dredges and seine (González-Liboy, 1971), quadrants (Flores, 2004), and PVC cores of 0.025m^2 with 1 m separation (Ocaña et al., 2013; Torreblanca-Ramírez et al., 2014).

Molluscan shells are routinely collected and brought to laboratory. The molluscan specimens are classified using morphological characters and special features (Paredes et al., 2007; Aldea and Rosenfeld 2011; Kosyan et al., 2012; Ocaña et al., 2013; Poulami et al., 2014; Torreblanca-Ramírez et al., 2014; Vanmali, 2015). Shell characters used include shape, spire length and shape, mouth opening, opercular shape, umbilicus shape and size, color and ornamentation (Syafruddin Nasution and Zulkifli, 2014). Diversity and species richness are usually evaluated by employing the Shannon-Wiener Index (Paredes et al., 2007) and non-parametric multivariate analyses of variance (np-MANOVA) (Prado and Castilla, 2006). Concomitant, monthly frequency histograms on sediment granulometry have been generated and related to diversity (Ocaña et al., 2013).

Consequently, it seems clear that the beaches offer an excellent opportunity for the analysis and exact definition of a marine microhabitat (Bush, 1966), and for the validation of sampling techniques. Studies on marine invertebrates in sandy-beach communities in North Carolina (Dexter, 1969), Mexico (Esqueda et al., 2000), and Cuba (Ocaña et al. 2012) suggested that gastropods numerically dominated in the samples over bivalves. The abundance of gastropods decreased from supra-littoral to lower areas while the number of species increased. Meanwhile, Esqueda et al. (op. cit.) reported that the number of species of bivalves also increased from supra-littoral to the lower intertidal zone, and the abundance of individuals was higher in the area called mid-intertidal. Nevertheless, Paredes et al. (2007), in Peru, found that other animal groups (Copepoda, Insecta, Rhizaria, Rotifera, Cladocera) can be numerically important in beach communities. More studies are still needed worldwide, and especially in the

Caribbean, to increase the information about the malacological faunas on the local and regional scales.

Materials and Methods

Study Site

This study focused on four beaches located at the west coast of Puerto Rico: El Maní (Mayagüez), El Combate (Cabo Rojo), Córcega (Rincón) and Balneario Tres Hermanos (Añasco) (Figure 1). They were geo-referenced using Google Earth® program. Their coordinates, for the beginning to the ending of each beach, and their sand composition are shown in Table 1. Aerial photographs from the selected beaches were provided by Dr. Fernando Gilbes-Santaella, from the Department of Geology at the University of Puerto Rico, Mayagüez (Figures 2-5).

The beach profiles (Appendix A, A1-A4) were determined *a priori* by using Google Earth© (Table 2). Aerial photographies were obtained from the websites *1930 Porto Rico Aerial Image Database* and EarthExplorer® for images 1930 and 1950 of Cabo Rojo, Rincón and Mayagüez beach. Añasco beach was not part of the original study on shoreline changes. Dr. Fernando Gilbes-Santaella provided images from year 2010. ENVI (Environment for Visualizing Images) version 5.2 was used to process the images. The images of the years 1930, 1950 and 2010 were already georeferenced (Appendix A6 -A8). In ENVI, we used the ROI File tool to trace a polygon through the shorelines of the beaches between the years 1930, 1950 and 2010. Calculation of erosion or deposition was achieved by subtracting the areas of the beaches from different years. The area was reported square meters (m^2).

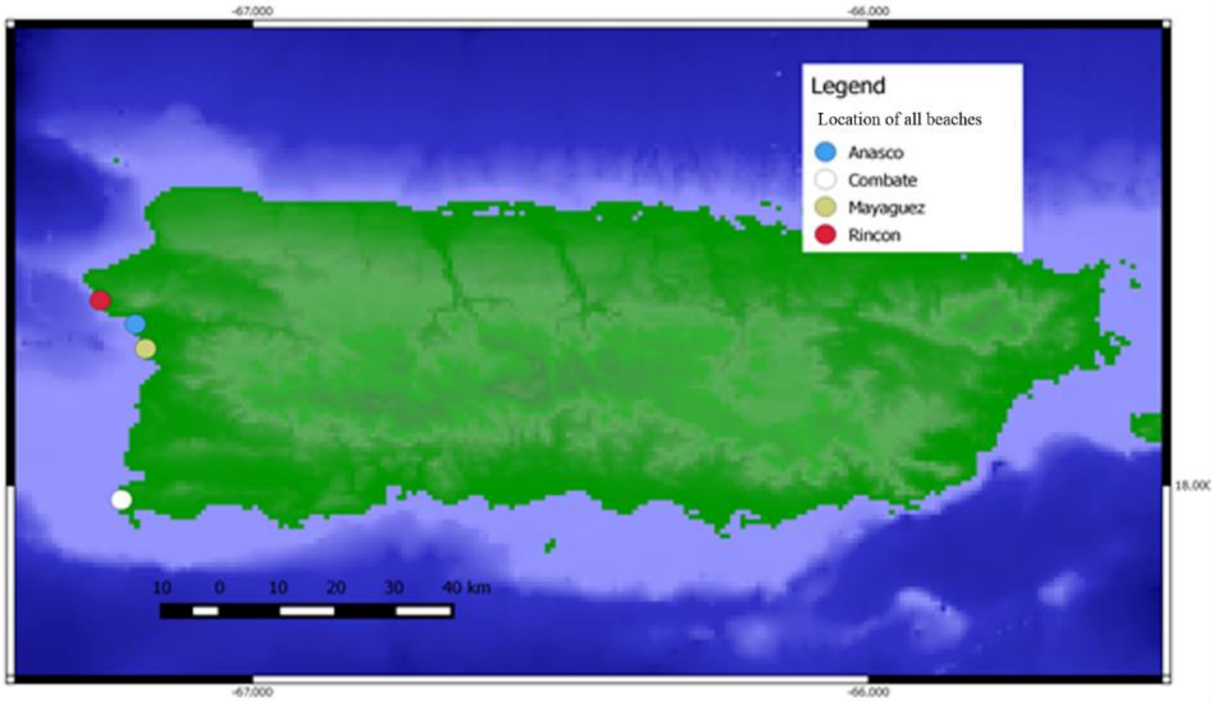

Figure 1. Location of selected beaches on the west coast of Puerto Rico, 2016.

Figure 2. 2010 Aerial Photography of El Combate beach, Cabo Rojo,2016.

Figure 3. 2010 Aerial Photography of Córcega beach, Rincón,2016.

Figure 4. 2010 Aerial Photography of El Maní beach, Mayagüez, 2016.

Figure 5. 2010 Aerial Photography of El Balneario Tres Hermanos beach, Añasco,2016.

Table 1. Coordinates (latitude and longitude) using Google Earth® and sand composition of the selected beaches.

Beach	Coordinates at the beginning of the beach	Coordinates at the end of the beach	Sand Composition
El Maní, Mayagüez	Latitude 18° 14’ 42’’N Longitude -067° 10’ 29’’W	Latitude 18° 13’ 50’’N Longitude -067° 10’ 23’’W	Volcanic debris, serpentine, quartz and coral detritus
El Combate, Cabo Rojo	Latitude 17° 58’ 12’’N Longitude -067° 12’ 44’’W	Latitude 17° 58’ 31’’N Longitude -067° 12’ 45’’W	Calcareous sand and is composed of quartz, fragments of corals and shells
Córcega, Rincón	Latitude 18° 19’ 32’’N Longitude -067° 14’ 59’’W	Latitude 18° 19’ 06’’N Longitude -067° 14’ 45’’W	Limestone debris, quartz and volcanic fragments
Balneario Tres Hermanos, Añasco	Latitude 18° 16' 57"N Longitude - 067° 11' 27"W	Latitude 18° 15' 57" N Longitude -067° 11'20"W	Carbonate shell material, quartz and feldspar, and igneous rock material, and dark minerals

Table 2. Calculation process for the beaches' profiles. Shorelines were determined using Google Earth®.

Beach	Shoreline (Km)	Meters (0.001 Km)	Divided by four transects
Cabo Rojo	1.84	1840	460m
Rincón	1.98	1980	495m
Mayagüez	1.58	1580	395m
Añasco	1.94	1940	485m

Field Work

Sites were visited at low tide, twice from August through November 2016 (Appendix A, Table A5). The reasons why we visited these beaches during low tide were because of the ease of access and because dozens of depressions and cracks occupied by shell-mollusks are exposed in some of the beaches.

Transect sampling

Four perpendicular transects were set every 100 m in the selected beaches (avoiding turtle nests), between swash mark and swash zone, and six samples were collected (beach face; Figure 8) by digging around 400 g the sand at 10cm of depth. Mollusks were collected *in situ*, either by manual removal from the sand zone or with a core-borer (PVC plastic tube) from the aquatic zone. Samples were classified as follows: 1-3 from the sand zone (swash zone) and 4-6 from the aquatic zone (Figure 8). The sediments collected were immediately placed in resealable plastic bags, labeled with the standard information: transect, date (month/day/year), time, and location (Combate, Córcega, Tres Hermanos or El Maní). The specimens remaining in the samples were removed upon arrival to the laboratory.

Quadrat Sampling

Species of *Littorina* as well as other similar snailsand limpets, inhabit in rocky shores. In rocky substrates, a 2 x 2 feet (0.093 m^2) PVC quadrat was used to count individuals (Figure 9). A total of 6 quadrats were laid on the shore moving from water level to upline to 3 meters. Mollusks were collected manually, counted and released during both times.

Laboratory Work

The specimens remaining in the sediments were reviewed and identified. The identification and characterization of the species, was performed with the references available at the Aquatic Laboratory (UPR-Mayagüez) (Warmke and Abbott Tucker, 1975; Morris, 1952; Joglar et al., 2014) and the followings: Bowling (2012-2015), Des Beechey (2005), Field Museum of Natural History (2016), National Oceanic and Atmospheric Administration National Ocean Service (2016), Smithsonian Marine Station at Fort Pierce Species Inventory (2016), The Delaware Geological Survey (2016), Poppe and Poppe (1996-2016), University of California Museum of Paleontology (2016), among others.

Selected specimens of every shell-mollusk species were photographed using a Photo-Stacking System Other sand-dwelling species, besides shell-mollusks, were kept for future studies.

Measurements of Grain Size and Sorting (Granulometry)

To characterize the sediment, 100 grams of each sample were run through a set of sieves to break the sample into subsets of size classes. For grain-size analysis, the sand samples were washed to reduce excess of salt and were oven-dried to eliminate humidity. They were processed through sieves ranging from -1 Φ to 4 Φ, ending with the pan sieve. The Udden-Wentworth grain-size scale and (Table 3) was used as a guideline to classify the sediments. Variation in grain size in elastic sedimentary rocks is known as sorting. A well-sorted sedimentary rock shows little variation in grain diameter; a poorly sorted (Figure 6) sedimentary rock exhibits large deviations from the mean grain size (Figure 7). Granulometric traits used were mean, median, median, mode, standard deviation, skewness (the quality, state, or condition of being distorted or lacking symmetry), and kurtosis (the quality, state, of condition of peakedness or flatness of the graphic representation of a statistical distribution). Grain-size and its attribute (i.e. sorting) were correlated to the abundance and richness of gastropods and bivalves in the samples.

Sieve Analysis

Sand samples were oven-dried at temperatures of 70-80 °C for 3 days. Approximately 100 g of sand were selected, and the shell-mollusks were removed, and these shells were weighted apart from the rest of the sub-samples A set of sieves were stacked such as the screen with the smallest opening wass at the base and the largest wass at the top. Sieves were shaken with a circular motion and occasionally rapped gently on the bench for 15 minutes. The sand was collected on weighing paper or a pan. Grains were transferred from each size-fraction to the weighing pan.

A histogram was constructed on the size-frequency of the grains for each sub-sample. The tallest column in the histogram indicates the mode of the grain size distribution (appendices B-H). A plot of grain size in phi values (x-axis) versus cumulative frequency (y-axis) was constructed. The y-axis was a scale of percent (0 to 100%) using a linear scale (uniform spacing). For each sample, a similar plot of grain size versus cumulative frequency was constructed. The cumulative curves for the samples were used to determine the phi size for each of the following phi values: 5% (φ5), 16% (φ16), 25% (φ25), 50% (φ50), 75% (φ75), 84% (φ84), and 95% (φ95) (where the % refers to the cumulative percent) with the following formulas:

Mode- the most frequent size category and determined as the largest column of the histogram.

Graphic Median – 50% above and 50% below this category

The phi value at 50% is the **Median** of the sample or grain population.

Graphic Mean – the average size category

$$M=\frac{\phi 16+\phi 50+\phi 84}{3}$$

Sorting- measure the grain-size variation of a sample (introduced Inclusive Graphic Standard Deviation)

$$\sigma 1 = \frac{\phi 84 - \phi 16}{4} + \frac{\phi 95 - \phi 5}{6.6}$$

Inclusive Graphic Skewness – shows if the distribution is bell shaped or shifted to side

$$S = \frac{\phi 84 + \phi 16 - 2(\phi 50)}{2(\phi 84 - \phi 16)} + \frac{\phi 95 + \phi 5 - 2(\phi 50)}{2(\phi 95 - \phi 5)}$$

Kurtosis – shows if the distribution is bell shaped, very flat, or very peaked

$$K = \frac{\phi 95 - \phi 5}{2.44(\phi 75 - \phi 25)}$$

Table 3. The Udden-Wentworth classification of grain-size. FromProthero and Schwab (2013).

Millimeters (mm)		Micrometers (µm)	Phi (φ)	Wentworth size class		Rock type
	4096		-12.0	Boulder	Gravel	Conglomerate/ Breccia
	256		-8.0	Cobble		
	64		-6.0	Pebble		
	4		-2.0	Granule		
	2.00		-1.0	Very coarse sand	Sand	Sandstone
	1.00		0.0	Coarse sand		
1/2	0.50	500	1.0	Medium sand		
1/4	0.25	250	2.0	Fine sand		
1/8	0.125	125	3.0	Very fine sand		
1/16	0.0625	63	4.0	Coarse silt	Silt	Siltstone
1/32	0.031	31	5.0	Medium silt		
1/64	0.0156	15.6	6.0	Fine silt		
1/128	0.0078	7.8	7.0	Very fine silt		
1/256	0.0039	3.9	8.0	Clay	Mud	Claystone
	0.00006	0.06	14.0			

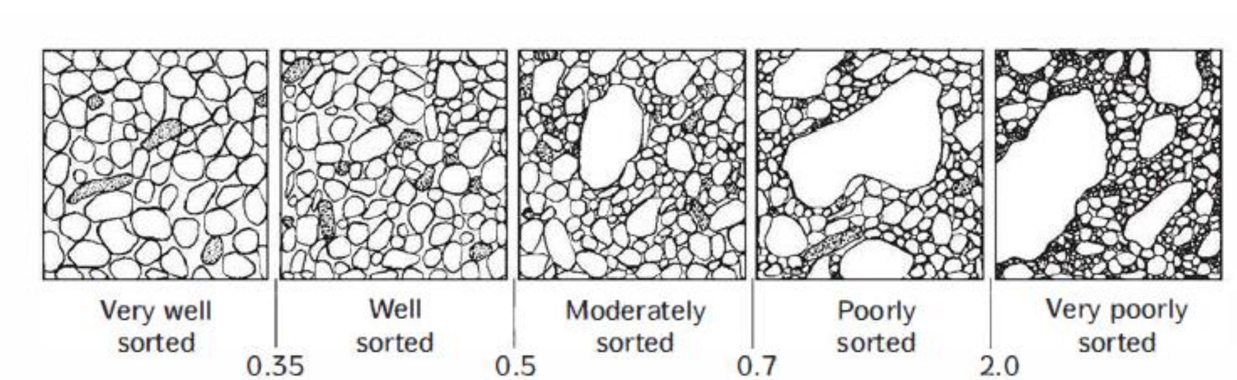

Figure 6. Standard images for visually estimating sorting expressed from very well sorted to very poorley sorted sample. From Prothero and Schwab (2013).

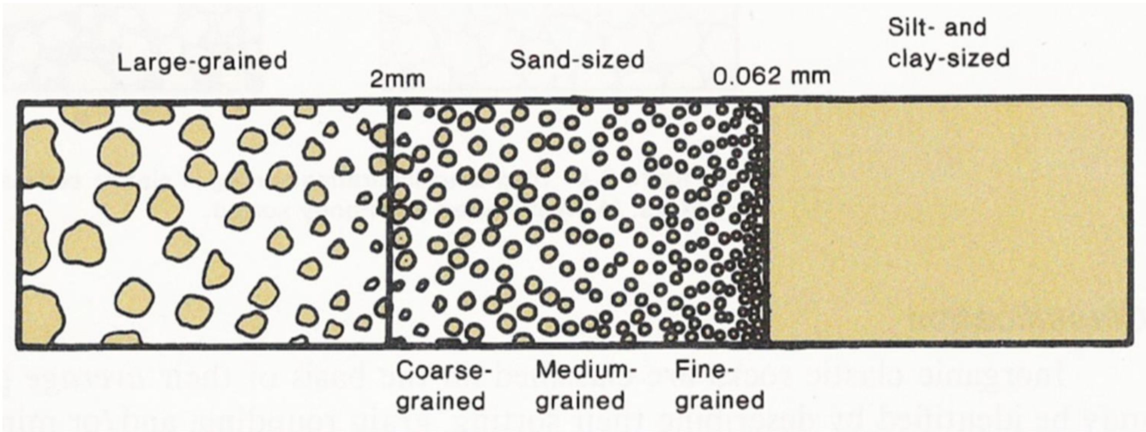

Figure 7. Standard images for visually estimating grain size expressed in large- grained, sand sized, silt and clay-sized. From Prothero and Schwab (2013).

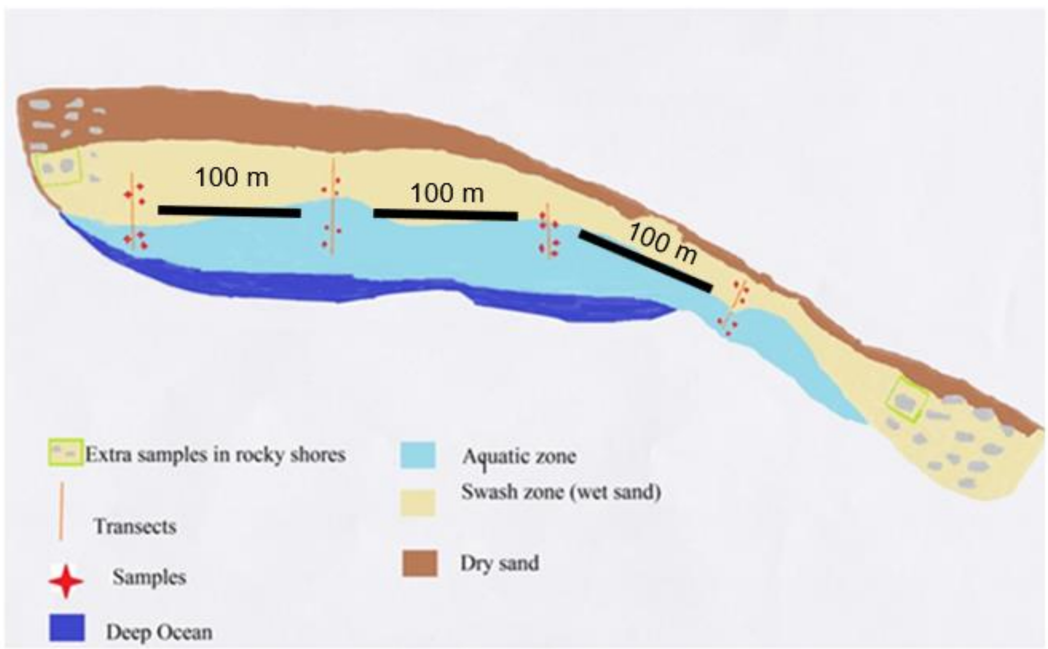

Figure 8. Diagram showing sand sampling strategy that included four transects on each selected beach.

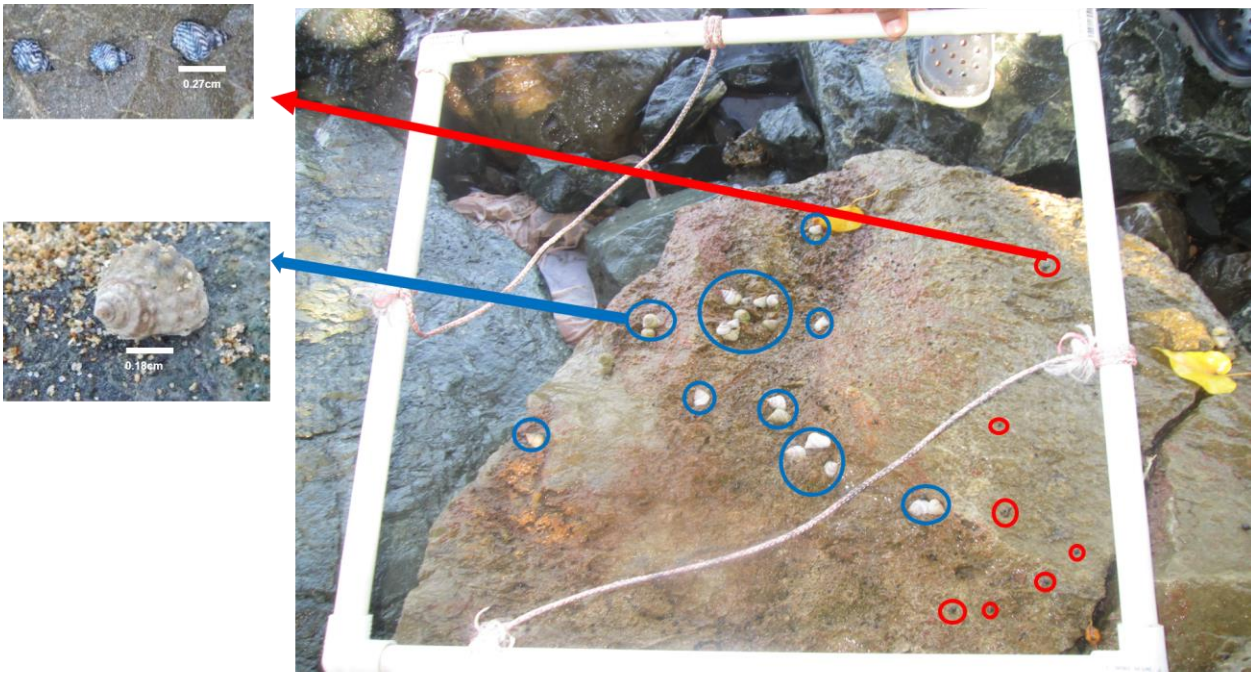

Figure 9. Example of the mollusks sampling strategy using a PVC quadrat deployment to obtain samples from rocky shores at El Maní, Mayagüez with photos of the respective species: gastropods *Cenchitris muricatus* (blue arrow) *Echinolittorina ziczac* (red arrow).

Statistical Analyses

Abundances of mollusk species were determined in two ways, such as relative abundance and cumulative abundance (turned later into cumulative frequencies). Relative abundance was referred to the number of individuals of a species in a set of samples collected from a given transect and date divided in by the total of number of individuals in the samples. Cumulative frequency was the number of individuals of that species in any given sample, transect or beach per visit.

A principal component analysis (PCA) was conducted to explain the spatial distribution regarding the granulometry (dissolved texture preference meaning the particle grain size). Using SAS and Infostat softwares, several ANOVAs, Tukey, and T-tests were performed to determine the relationships between mollusk diversity (richness and abundance) and the following factors:

habitats such as sandy beaches versus rocky beaches, the number of transects, the study site (local beaches), swash zone (wet sand area) versus aquatic zone, both samplings (I, II), and bivalves versus snail mollusks for communities in each of the four beaches. All samples are stored in the laboratory for further research projects.

Dispersion Index was applied to the counts of the *Echinolittorina* and *Tectarius* snails and performed with the aid of quadrats. This Index is usually defined as the ratio of the variance to the mean. By counting the number of individuals within each sampling plot, we can see how the density of individuals changes from one part of the habitat to another. Three types of spatial distributions are recognized: (1) individuals that spread evenly through the environment are highly dispersed, (2) individuals clumped together exhibit low dispersion, and (3) if organisms are attracted to one another, their population shows increased aggregation.

The Shannon-Wiener Index (H' or D), was used as a univariate measure of diversity where:

D = - pi • lnpi, where

D= Shannon Wiener diversity index,

Ln = natural logarithm; pi = ni / N;

ni = number of individuals of each taxa i,

N = total number of individuals (Paredes et al., 2007).

The Shannon-Wiener index is an ecological index of diversity, that measures the information content per individuals in samples obtained from a community based on two factors: the number of species present and their respective abundances. The conversion of the results from this index to Effective Number of Sspecies is achieved by ln-transformation (Jost, 2006). The Shannon-Wiener Index was used to calculate the diversity of gastropods and bivalves population (i.e. comparing percentages of the diversity of species in a different sites) in both samplings at the four selected beaches. We also tested if there were significant differences in the number of individuals (abundances) or species (richness) between beaches, samplings, transects and zones (sand versus aquatic).

Jaccard Index of Similarity (Jaccard similarity coefficient) measures the similarity between two sets of data, with a range from 0% to 100%. The higher the percentage, the more similar the two populations are. We used the Jaccard's Index in its two variations ([J=C/(A+B+C)] and [J=C/(A+B-C)]) to compare species composition among the selected four beaches and among their respective transects. The formula on Jaccard is based on:

$S_J = C/ (A + B + C)$ or, $S_J = C/(A + B-C)$ where

S_J = Jaccard similarity coefficient,

C = number of species present (shared by) in both data sets,

A= number of species unique to the first data set, and

B = number of species unique to the second data set

Principal Component Analysis (PCA) is a multivariate statistical technique that analyses a data table representing observations described by several dependent variables, which are generally inter-correlated, and represents the pattern of similarity of observations and the variables by displaying them as points in a map (Abdi and Williams, 2010). PCA with Biplot-scatterplot was used to describe the strongest patterns in species composition among beaches.

Results

Shoreline Changes by image process in ENVI

By using ROI File in ENVI, we calculated shoreline changes due to erosion or deposition within the study areas of the selected beaches Also, using ROI. File helped distinguish shoreline changes from the years 1930, 1950 and 2010 (Figures 10-12, Appendix A, A9- A11). The equation used subtracted the area from a recent image (i.e., images from 2010) from the area of a previous image (images from 1930 or 1950); thus, positive values indicated erosion and negative values corresponded to deposition. Cabo Rojo and Rincón beaches showed erosion. El Maní beach was the only one that showed deposition in its shoreline (Table 4).

Table 4. Calculation of erosion or deposition in Cabo Rojo, Rincón and Mayagüez beaches.

Beach	1930 Area m^2	1950 Area m^2	2010 Area m^2	Difference m^2	Water more/less	Erosion or Deposition
Cabo Rojo	280,731.18m^2	________	295,417.08m^2	-14685.9m^2	More	Erosion
Rincón	________	617,278.68m^2	625,120.47m^2	-7841.79m^2	More	Erosion
Mayagüez	________	3481287.93m^2	3409974.18m^2	71313.75m^2	Less	Deposition

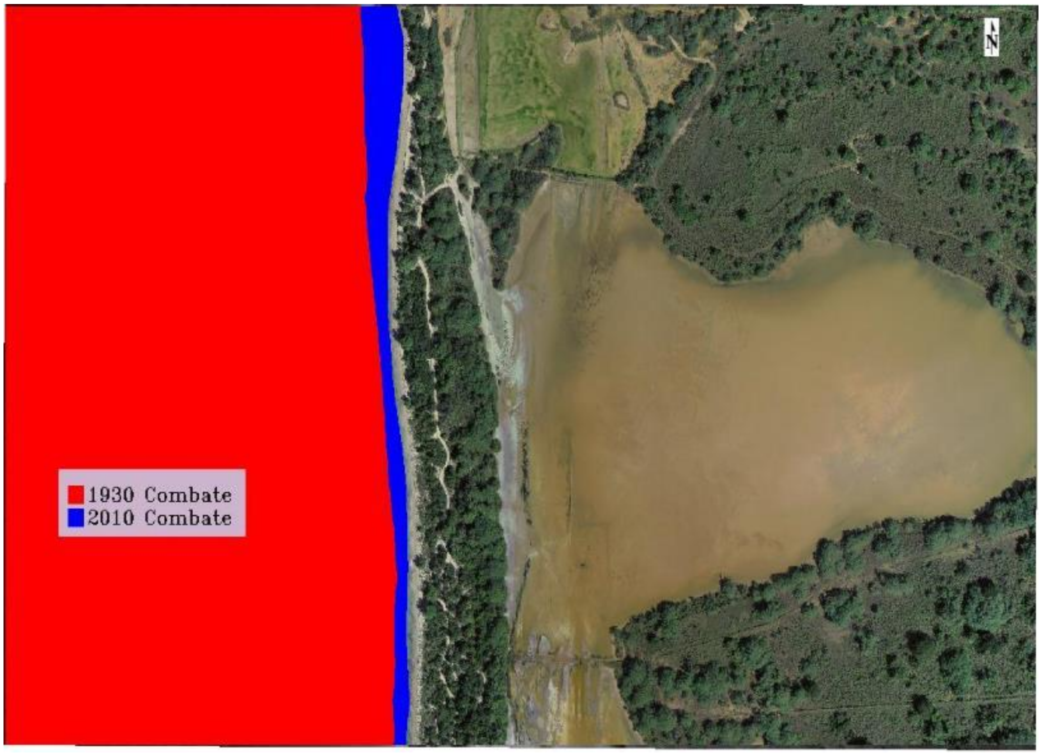

Figure 10. Shoreline changes from 1930 (red polygon) to 2010 (blue polygon), based on aerial images, at El Combate beach, Cabo Rojo.

Figure 11. Shoreline changes from 1950 (orange polygon) to 2010 (blue polygon), based on aerial images, at Córcega beach, Rincón.

Figure 12. Shoreline changes from 2010 (blue polygon) and 1950 (orange polygon), based on aerial images, at El Maní beach, Mayagüez

Mean values for sand composition on the selected beaches

During our first sampling period (August/September), all samples (1-6) collected from the four transects at Cabo Rojo beach, were analyzed to determine grain size and sorting characted along different locations along the beach. Since all the samples from each zone (beach face and swash zone) at different locations showed similar grain size and sorting (see cumulative frequency graphs in Figure 12 and Appendix D), further analyses only included one sample from each zone.

According to the Udden-Wentworth size class (Table 3), most samples from Cabo Rojo ranged within the sand size classification, except for one that was in the gravel size class. Table 5 shows grain particle size for samples numbered as either 1 or 4 and collected from the four beaches and both samplings. The sand size class of the selected beaches ranged from fine (125 μm) to very coarse (1000 μm). As mentioned before, there was a sample that was sorted into the gravel classification, and it was collected at Combate beach, Cabo Rojo, during sampling 2 (Table 5). This sample was further categorized into the granule size class (2000 μm). This is probably since the sands of Cabo Rojo are usually coarser and have a lot of quartz in their composition, which causes the sand particles to not break or erode as easily (Tables 5-6, Figures 13, 15-16).

The beach face during sampling 1 (August/September) at Combate beach is different from those of other beaches since it had coarser and poorly sorted grains, while the other beaches had well sorted and finer grains (Figure 13). The beach face sand zone of this beach had a finer grain size during sampling 2 (October/November) as compared to sampling 1 (August/September). This could be due to swells caused by cold fronts that are abundant in the months of October and November. Also, the grain particles of the sand zone at Córcega beach, Rincón, were coarser and poorly sorted during sampling 2 (October/November) when compared to the other beaches (Figure 14).

The grain size in the aquatic zone (swash zone) during sampling 1 (August/September) showed that sample 4 from transect 4 in Balneario Tres Hermanos, Añasco, and sample 4 from transect 4 in Córcega, Rincón, were different from samples numbered 4 in the other two beaches. The first two beaches (Añasco and Rincón) had thick sand grains, similar in size and corresponding to medium sand (250 μm) (Figure 15). Furthermore, a similar pattern can be seen in the graph for sampling 2 (October/November) for the same samples (#4), transects (#4) and beaches (Añasco and Rincón) (Figure 16). The aquatic zone of the selected beaches showed similar results during the two sampling periods; sand from Combate beach was poorly sorted with coarser grain size; those from Añasco and Rincón had medium grain size; and that from Maní, Mayagüez, was well sorted and had a finer grain size (Figures 15-16). All the graphs of cumulative frequency for the particle grain size distributions are in Appendix J (J1-J12).

Table 5. Sand particle size (μm) and sand class of samples from all transects at the selected beaches and from both samplings. Sand particle size-range is 125-2000 μm.

Sampling	Beach	Transect	Sample	Mean (ϕ)	Sand class	Sand particle size (μm)
Sampling 1	Cabo Rojo	T1	1	0.50	Very coarse	1000
		T1	4	0.01	Very coarse	1000
		T2	1	1.37	Medium	250
		T2	4	0.35	Very coarse	1000
		T3	1	1.37	Medium	250
		T3	4	0.42	Very coarse	1000
		T4	1	1.47	Medium	250
		T4	4	-0.48	Very coarse	1000
	Añasco	T1	1	2.04	Medium	250
		T1	4	1.00	Coarse	1000
		T2	1	1.26	Medium	250
		T2	4	1.83	Medium	250
		T3	1	1.70	Medium	250
		T3	4	0.94	Coarse	1000
		T4	1	1.77	Medium	250
		T4	4	0.79	Coarse	1000
	Rincón	T1	1	1.62	Medium	250
		T1	4	1.54	Medium	250
		T2	1	1.40	Medium	250

Table 5 Continuation

Sampling	Beach	Transect	Sample	Mean (ϕ)	Sand class	Sand particle size (µm)
		T2	4	1.52	Medium	250
		T3	1	1.89	Medium	250
		T3	4	1.66	Medium	250
		T4	1	2.04	Medium	250
		T4	4	0.71	Coarse	1000
	Mayagüez	T1	1	1.88	Medium	250
		T1	4	1.60	Medium	250
		T2	1	1.70	Medium	250
		T2	4	1.24	Coarse	1000
		T3	1	1.84	Medium	250
		T3	4	0.74	Coarse	1000
		T4	1	1.79	Medium	250
		T4	4	1.36	Medium	250
Sampling 2	Cabo Rojo	T1	1	1.65	Medium	250
		T1	4	0.60	Coarse	1000
		T2	1	1.74	Medium	250
		T2	4	1.20	Coarse	1000
		T3	1	1.63	Medium	250
		T3	4	-0.20	Very coarse	1000
		T4	1	1.43	Medium	250
		T4	4	-1.33	Granule (gravel)	2000
	Añasco	T1	1	1.60	Medium	250
		T1	4	0.98	Coarse	1000
		T2	1	1.44	Medium	250
		T2	4	1.24	Coarse	1000

Table 5 Continuation

Sampling	Beach	Transect	Sample	Mean (ϕ)	Sand class	Sand particle size (µm)
		T3	1	1.65	Medium	250
		T3	4	0.40	Coarse	1000
		T4	1	1.63	Medium	250
		T4	4	0.60	Coarse	1000
	Rincón	T1	1	0.89	Coarse	1000
		T1	4	1.80	Medium	250
		T2	1	1.59	Medium	250
		T2	4	1.57	Medium	250
		T3	1	1.48	Medium	250
		T3	4	1.23	Medium	250
		T4	1	1.71	Medium	250
		T4	4	1.04	Coarse	1000
	Mayagüez	T1	1	2.06	Fine	125
		T1	4	2.12	Fine	125
		T2	1	1.91	Medium	250
		T2	4	1.93	Medium	250
		T3	1	1.91	Medium	250
		T3	4	2.29	Fine	125
		T4	1	2.03	Fine	125
		T4	4	1.78	Medium	250

Table 6. Sorting values and sorting categories of samples from all transects at the selected beaches and from both samplings

Sampling	Beach	Transect	Sample	Mean	Sorting values	Sorting categories
Sampling 1	Cabo Rojo	T1	1	0.50	1.66	poorly sorted
		T1	4	0.01	1.97	poorly sorted
		T2	1	1.37	1.31	poorly sorted
		T2	4	0.35	1.68	poorly sorted
		T3	1	1.37	1.3	poorly sorted
		T3	4	0.42	1.67	poorly sorted
		T4	1	1.47	1.22	poorly sorted
		T4	4	-0.48	2.2	very poorly sorted
	Añasco	T1	1	2.04	1.41	poorly sorted
		T1	4	1.00	1.34	poorly sorted
		T2	1	1.26	1.44	poorly sorted
		T2	4	1.83	1.31	poorly sorted
		T3	1	1.70	1.44	poorly sorted
		T3	4	0.94	1.46	poorly sorted
		T4	1	1.77	1.3	poorly sorted
		T4	4	0.79	1.5	poorly sorted
	Rincón	T1	1	1.62	1.3	poorly sorted
		T1	4	1.54	1.31	poorly sorted
		T2	1	1.40	1.3	poorly sorted
		T2	4	1.52	1.28	poorly sorted
		T3	1	1.89	1.29	poorly sorted
		T3	4	1.66	1.28	poorly sorted
		T4	1	2.04	1.37	poorly sorted
		T4	4	0.71	1.63	poorly sorted

Table 6 Continuation

Sampling	Beach	Transect	Sample	Mean	Sorting values	Sorting categories
	Mayagüez	T1	1	1.88	1.31	poorly sorted
		T1	4	1.60	1.39	poorly sorted
		T2	1	1.70	1.37	poorly sorted
		T2	4	1.24	1.44	poorly sorted
		T3	1	1.84	1.32	poorly sorted
		T3	4	0.74	1.6	poorly sorted
		T4	1	1.79	1.31	poorly sorted
		T4	4	1.36	1.39	poorly sorted
Sampling 2	Cabo Rojo	T1	1	1.65	1.42	poorly sorted
		T1	4	0.60	1.59	poorly sorted
		T2	1	1.74	1.35	poorly sorted
		T2	4	1.20	1.33	poorly sorted
		T3	1	1.63	1.44	poorly sorted
		T3	4	-0.20	2.05	very poorly sorted
		T4	1	1.43	1.34	poorly sorted
		T4	4	-1.33	2.67	very poorly sorted
	Añasco	T1	1	1.60	1.39	poorly sorted
		T1	4	0.98	1.46	poorly sorted
		T2	1	1.44	1.35	poorly sorted
		T2	4	1.24	1.39	poorly sorted
		T3	1	1.65	1.32	poorly sorted
		T3	4	0.40	1.69	poorly sorted
		T4	1	1.63	1.35	poorly sorted
		T4	4	0.60	1.6	poorly sorted
	Rincón	T1	1	0.89	1.41	poorly sorted
		T1	4	1.80	1.3	poorly sorted

Table 6 Continuation

Sampling	Beach	Transect	Sample	Mean	Sorting values	Sorting categories
		T2	1	1.59	1.3	poorly sorted
		T2	4	1.57	1.34	poorly sorted
		T3	1	1.48	1.32	poorly sorted
		T3	4	1.23	1.51	poorly sorted
		T4	1	1.71	1.28	poorly sorted
		T4	4	1.04	1.49	poorly sorted
	Mayagüez	T1	1	2.06	1.35	poorly sorted
		T1	4	2.12	1.4	poorly sorted
		T2	1	1.91	1.43	poorly sorted
		T2	4	1.93	1.37	poorly sorted
		T3	1	1.91	1.37	poorly sorted
		T3	4	2.29	1.41	poorly sorted
		T4	1	2.03	1.35	poorly sorted
		T4	4	1.78	1.37	poorly sorted

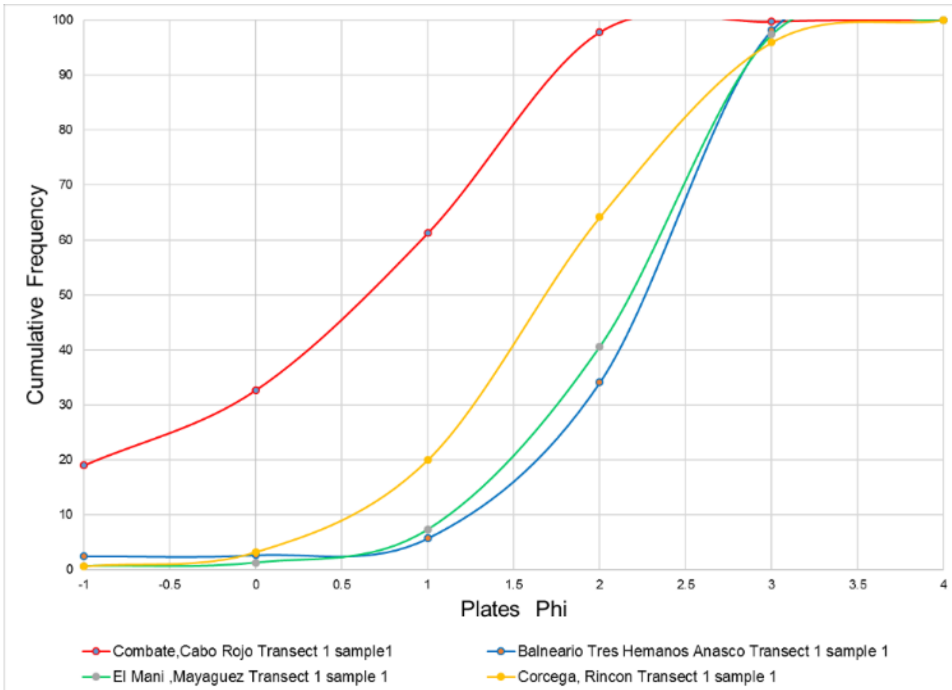

Figure 13. Cummuative frequency curve showing granulometry of the beach face sand zone, during sampling 1 (August/September 2016), for all locations. Well sorted values of Mayagüez, Rincón and Añasco contrast with the poorly sorted values from Cabo Rojo.

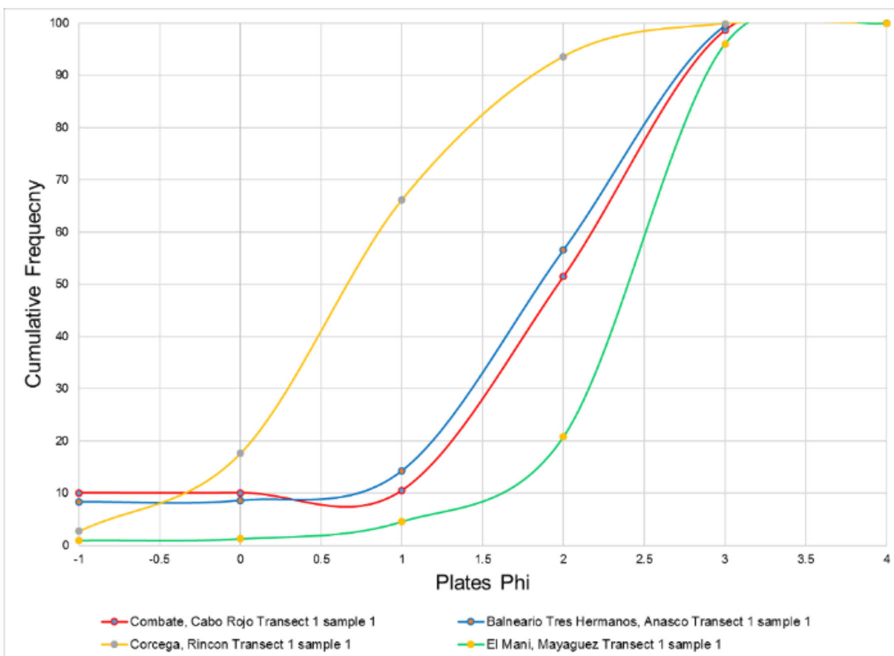

Figure 14. Cummuative frequency curve showing granulometry of the beach face sand zone, during sampling 2 (October/November 2016), for all locations. Larger grain size of Mayagüez contrast with the smaller grain seize of Rincón, Añasco and Cabo Rojo.

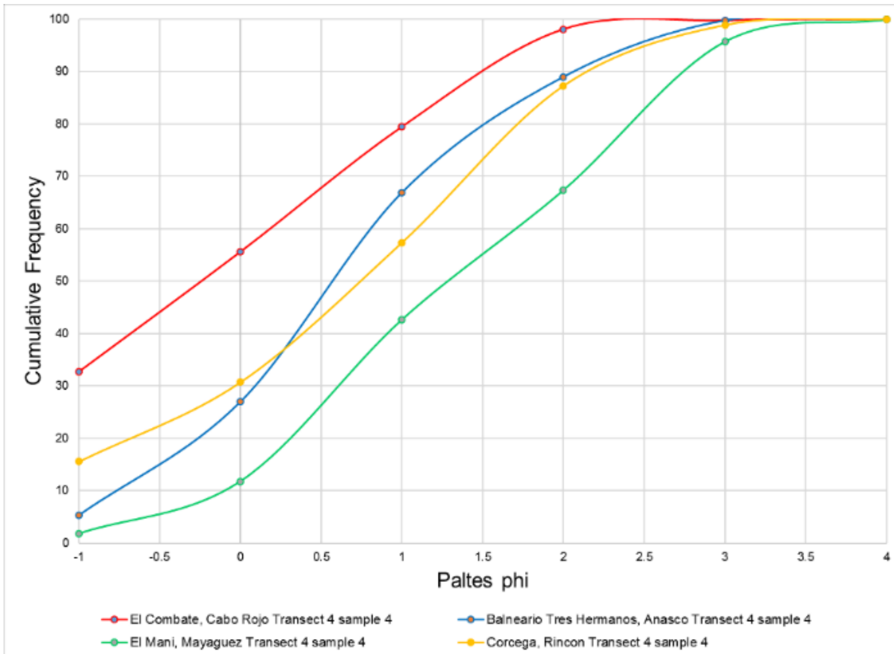

Figure 15. Cummuative frequency curve showing granulometry of the swash zone during sampling 1 (August/September 2016) for all locations. Studied locations showed poorly sorted sediments.

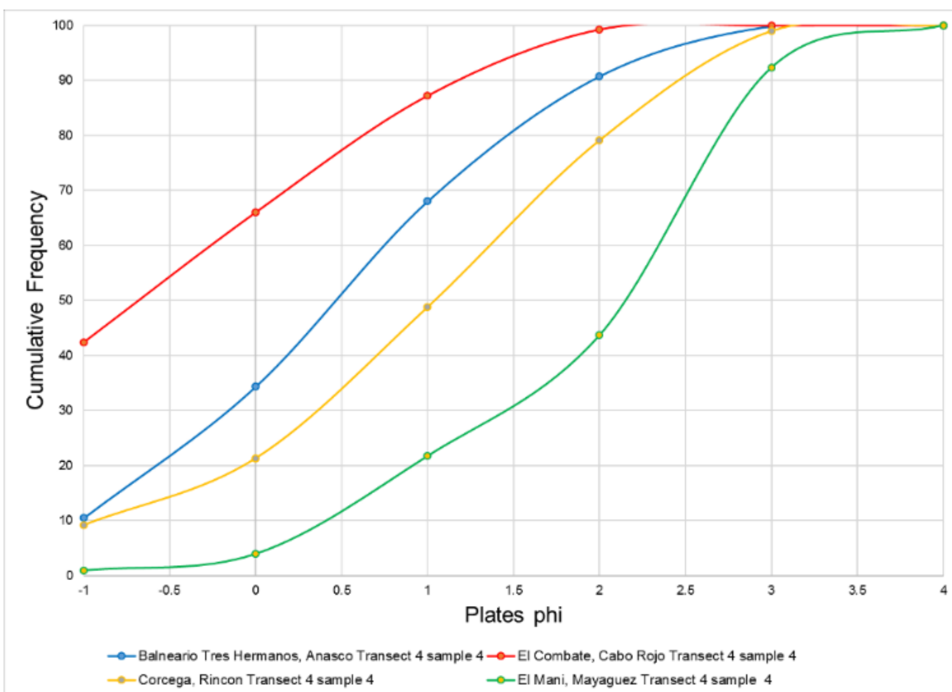

Figure 16. Cummuative frequency curve showing granulometry of the swash zone during sampling 2 (October/November 2016) for all locations. Studied locations showed sorting variations.

ANOVA analysis for sediment sorting in the selected beaches showed highly significant differences for the variables beach (p=0.0005) and zone (p=0.0003). Tukey test suggested significant differences between beaches and zone in the variables beach and zone (Appendix P, P1-P4).

Table 7. ANOVA (SC type III) for sediment sorting in the selected beaches, according to the variables samplings, beach, transects and zone (sand vs. aquatic). N= 64. Red p-values represent significant differences (α<0.05). CV=13.35%.

Source	d.f.	SS	MS	F	p-value
Model	8	1.53	0.19	5.11	0.0001
Samplings	1	0.01	0.01	0.17	0.6811
Beach	3	0.78	0.26	6.92	0.0005
Transects	3	0.18	0.06	1.63	0.1920
Zone	1	0.56	0.56	15.00	0.0003
Error	55	2.06	0.04		
Total	63	3.59			

Species abundance at the selected beaches

A total of 391 individuals (212 Bivalvia and 179 Gastropoda) were collected during sampling 1 (August/ September 2016), whereas a total of 482 individuals (173 Bivalvia and 309 Gastropoda) were collected during sampling 2 (October/November 2016). Cabo Rojo beach had the greastest abundances, with 166 individuals (150 Bivalvia and 16 Gastropoda) recorded in sampling 1 and 354 individuals (61 Bivalvia and 293 Gastropoda) in sampling 2. Añasco beach followed in abundances, where sampling 1 rendered 139 individuals (121 Bivalvia and 18 Gastropoda) and sampling 2 rendered 53 individuals (42 Bivalvia and 11 Gastropoda). In Rincón, 28 individuals (17 Bivalvia and 11 Gastropoda) were collected while 9 individuals (7

Bivalvia and 2 Gastropoda) in sampling 2. Lastly, Mayagüez beach only rendered bivalve species, 12 individuals in sampling 1 and 7 individuals in sampling 2.

Species richness at the selected beaches

Table 8 shows the 81 species of bivalves and 50 species of gastropods that were found in the whole study. All bivalves and gastropods species are illustrated in Appendix P. *Cerion striatella* is a terrestrial snail found in samples from Cabo Rojo. This species is part of the terrestrial xeric environment common along the coast and might have been washed into the shore. Bivalves *Donax denticulatus*, *D. striatus* and *D. variabilis* were common species that occurred in all beaches. The gastropods *Diodora sp.*, *Olivella sp*. and *Cyphoma gibbosum* were found in Cabo Rojo, Añasco and Rincón. Gastropods were not found at El Maní beach, Mayagüez. This could be due to the fact that this beach has almost no noncarbonate beach deposits (Guillou and Glass, 1957). Gastropods species *Echinolittorina ziczac* and *Cenchitris muricatus* were not included in Table 7, since these species were found only at rocky shorelines at Rincón and Mayagüez beaches and did not occur in the sand samples.

Table 8. Species of shell-mollusks in sand samples from the beaches Mayagüez (M), Cabo Rojo (CR), Añasco (A) and Rincón (R) in sampling I (August/September 2016) and sampling II (October/November 2016). *Cerion striatella* is a terrestrial snail.

Class	Family	Species	Site (Sampling)
Bivalvia	Anomiidae	*Anomia simplex*	CR (I), A (I,II), R(I)
	Arcidae	*Anadara chemnitzii*	A (I), CR (II)
		Anadara lienosa floridana	A (I)
		Anadara notabilis	A (I), CR (II)
		Anadara sp.	A (I), M (I)

Table 8 Continuation

Class	Family	Species	Site (Sampling)
		Anadara transversa	A (I), CR (II)
		Arca imbricata	CR (II), A (II)
		Arca sp.	A (I)
		Arca zebra	CR (I,II), A(I)
		Barbatia candida	CR (II)
		Barbatia sp.	A (I)
		Lunarca ovalis	CR (II)
	Basterotiidae	*Basterotia sp.*	A (I)
	Cardiidae	*Acrosterigma magnum*	A (I)
		Americardia guppyi	M (I,II)
		Americardia media	CR (I,II), M (II)
		*Americardia sp.*1	M (I)
		Americardia sp. 2	CR (II)
		Dinocardium robustum	CR (II)
		Laevicardium mortoni	A (I)
		Laevicardium sp.	CR (II)
		Microcardium sp.	CR (I,II)
		Trachycardium egmontianum	A (I)
		Trachycardium sp. 1	CR (II), A (II)
		Trachycardium sp. 2	A (I)
		Trigoniocardia antillarum	M (I)
	Carditidae	*Cardita sp.*	A (I)
		Carditamera gracilis	A (I)
	Chamidae	*Chama macerophylla*	A (I)
		Chama sarda	A (I)
		Chama sp.	A (I,II), R (I), CR (II)

Table 8 Continuation

Class	Family	Species	Site (Sampling)
	Cuspidariidae	*Cardiomya sp.*	A (I)
	Donacidae	*Donax denticulatus*	CR (I,II), A (I,II), M (I,II), R (II)
		Donax striatus	A (I), CR (II), M (I), R (I)
		Donax variabilis	A (I, II), M (I,II), R (II), CR (II)
	Dreissenidae	*Mytilopsis sp.*	A (I)
	Gastrochaenidae	*Gastrochaena sp.*	A (I)
	Glycymerididae	*Glycymeris decussata*	CR(I), A (I)
		Glycymeris pectinata	A (I), CR (II)
		Glycymeris undata	A (I)
		Glycymeris sp.	A (I)
	Lasaeidae	*Erycina sp.*	A (I)
	Limidae	*Ctenoides scaber*	A (I)
		Lima sp.	R (I)
		Limaria pellucida	A (II)
	Lucinidae	*Lucina pensylvanica*	CR (II)
	Mactridae	*Mulinia sp.*	M (I)
	Myidae	*Sphenia sp.*	A (I,II)
	Mytilidae	*Adula sp.*	A (I)
		Brachidontes sp.	R (I)
		Ischadium recurvum	A (I)
	Noetiidae	*Arcopsis adamsi*	A (II)
		Arcopsis sp.	A (II)
	Ostreidae	*Teskeyostrea sp.*	A (I)
	Pectinidae	*Argopecten sp.*	R (I)
		Caribachlamys ornata	R (II)
	Pholadidae	*Martesia sp.*	A (I)

Table 8 Continuation

Class	Family	Species	Site (Sampling)
	Plicatulidae	*Plicatula gibbosa*	CR (I,II)
	Potamididae	*Cerithidea sp*	CR (II)
	Semelidae	*Semelina nuculoides*	CR (I)
	Spheniopsidae	*Grippina sp.*	R (I), A (II)
	Tellinidae	*Macoma sp.*	A(I)
		Laciolina magna	A (I)
		Strigilla carnaria	M (I)
	Thraciidae	*Thracia stimpsoni*	A (I)
	Ungulinidae	*Diplodonta notata*	CR (II)
		Diplodonta nucleiformis	A (I), CR (II)
		Diplodonta sp.	M (I)
	Veneridae	*Anomalocardia flexuosa*	CR (II)
		Chione cancellata	CR (I,II)
		Chione sp.	CR (I)
		Chionopsis sp.	CR (II)
		Chioneryx pygmaea	R(I)
		Gouldia sp.	A (I)
		Lamelliconcha circinata	A (I, II)
		Leukoma staminea	A (I)
		Megapitaria maculata	A (II)
		Pitar fulminatus	CR (I)
		Puberella intarpurpurea	M (I)
		Tivela sp.	A (I)
		Transennella stimpsoni	CR (II)
	Yoldiidae	*Yoldia limatula*	A (I, II), M (I)
		Yoldia sp.	R (II)

Table 8 Continuation

Class	Family	Species	Site (Sampling)
Gastropod	Architectonicidae	*Philippia sp.*	CR (II)
		Psilaxis krebsii	A (I), R (I)
		Architectonica nobilis	CR (II)
	Batillariidae	*Lampanella minima*	CR (II), R (II)
		Lampanella sp.	CR (I)
	Buccinidae	*Busycon sp.*	A (II)
	Calyptraeidae	*Sigapatella sp.*	CR (I,II)
	Cerionidae	*Cerion striatella**	CR (II)
	Cerithiidae	*Cerithidea sp.*	CR (I)
		Cerithideopsis costata	CR (I)
		Cerithium cf eburneum	CR (II)
		Cerithium sp.	CR (II)
		Lirobittium quadrifilatum	CR (II)
	Cerithiopsidae	*Cerithiopsis greeni*	CR (II)
	Columbellidae	*Columbella mercatoria*	CR (I,II)
		Columbella sp.	CR (II)
	Conidae	*Conus daucus*	A (II), R (I)
		Conus sp.	A (II)
	Fissurellidae	*Diodora aspera*	A (I, II)
		Diodora cayenensis	CR (II), A (II)
		Diodora listeri	A (I)
		Diodora variegata	CR (II)
		Diodora sp.	CR (II), A (I), R (I)
		Fissurella barbadensis	A (I)
		Fissurella fascicularis	A(I)
		Fisurella sp.	CR (II)

Table 8. Continuation

Class	Family	Species	Site (Sampling)
	Helicidae	*Rossmassleria sp.*	CR (I)
	Hipponicidae	*Hipponix antiquatus*	A (II)
		Hipponix incurvus	A (I)
		Hipponix subrufus	A (I), R (I)
	Littorinidae	*Littorina sp.*	CR (I)
	Marginellidae	*Marginella sp.*	CR (II)
	Modulidae	*Modulus sp.*	CR(II)
	Naticidae	*Natica sp.*	CR (I,II)
		Polinices sp.	A (II)
	Neritidae	*Nerita peloronta*	CR (II)
		Nerita tessellata	A(I)
		Smaragdia sp.	CR (II)
	Olividae	*Olivella minuta*	CR (I), A(I)
		Olivella sp.	CR (II), A (II), R (I)
		Olivia sp.	R (I)
	Ovulidae	*Cyphoma gibbosum*	CR (I, II), A (I), R (I)
		Cyphoma sp.	R (I)
	Pisaniidae	*Engina sp*	A (II), R (I)
	Planaxidae	*Planaxis sp.*	A (I)
	Pyramidellidae	*Odostomia sp.*	CR (I)
		Turbonilla elegans	CR (I), A (I)
		Turbonilla sp.	CR (I)
	Tegulidae	*Tegula sp.*	CR (II)
	Turritellidae	*Turritella variegata*	CR (II)
	Zebinidae	*Zebina browniana*	A (I)

Table 9 presents the cumulative richness of shell-mollusk species (gastropods and bivalves) for all the beaches and both samplings. Cabo Rojo beach rendered 65 shell-mollusks in which 10 species (4 gastropods and 6 bivalves) were found during both samplings (Tables 9-10). These species were the bivalves *Americardia media, Donax denticulatus, Arca zebra, Chione cancellata, Plicatula gibbosa, Microcardium sp*. and the snails *Sigapatella sp., Cyphoma gibbosum*, *Columbella mercatoria* and *Natica sp.* Samples from Añasco had 59 shell-mollusks species in sampling 1 and 24 shell-mollusks species in sampling 2, of which 8 species (1 gastropod and 7 bivalves) were found on both samplings (Table 10). The species found during both samplings in Añasco were the bivalves *Pitar circinatus*, *Donax denticulatus, D. variabilis, Sphenia sp., Anomia simplex, Chama sp.* and *Yoldia limatula*, and the gastropod *Diodora aspera*. Samples from Rincón had 23 shell-mollusk species and none of them occurred in both samplings. Lastly, samples from Mayagüez showed 16 bivalve species, with no gastropods at all, and three of the bivalve species were found during both samplings: *Donax denticulatus, D. variabilis* and *Americardia guppyi*.

Table 9. Cumulative richness of shell-mollusks (G= Gastropoda; B= Bivalvia) during both samplings (year 2016) at the selected beaches.

Beach	Species in sampling 1 (August/September)	Species in sampling 2 (October/November)	Shared Species	Cumulative Richness
El Combate, Cabo Rojo	23	52	10 G = 4 B = 6	65 G = 33 B-= 32
Balneario Tres Hermanos, Añasco	59	24	8 G = 1 B = 7	75 G = 23 B = 52

Córcega, Rincón	16	7	0	23 G = 10 B = 13
El Maní, Mayagüez	12	4	3 G = 0 B = 3	13 G = 0 B = 10

The snails *Sigapatella sp.* and *Olivella minuta* had the greatest cumulative frequencies in samples from Cabo Rojo (August 26, 2016). *Donax denticulatus* was the most frequent bivalve in Cabo Rojo (Figures 17-18), in Mayagüez (Figures 19-20) and Añasco (Figure 21). On the other hand, *Philippia sp.* and *Olivia sp.* (gastropods) and *Donax striatus* (bivalve) were the most frequent mollusks in Rincón (Figure 22). *Sigapatella sp.* (gastropod) and *Americardia media* (bivalve) were the most frequent ones in Añasco beach (Figure 23). Finally, the bivalve *Yoldia limatula* was the most frequent species in Rincón (Figure 24). All extra graphs on the abundaces of the gastropods and bivalves collected in the study are in Appendix J (J1-J14).

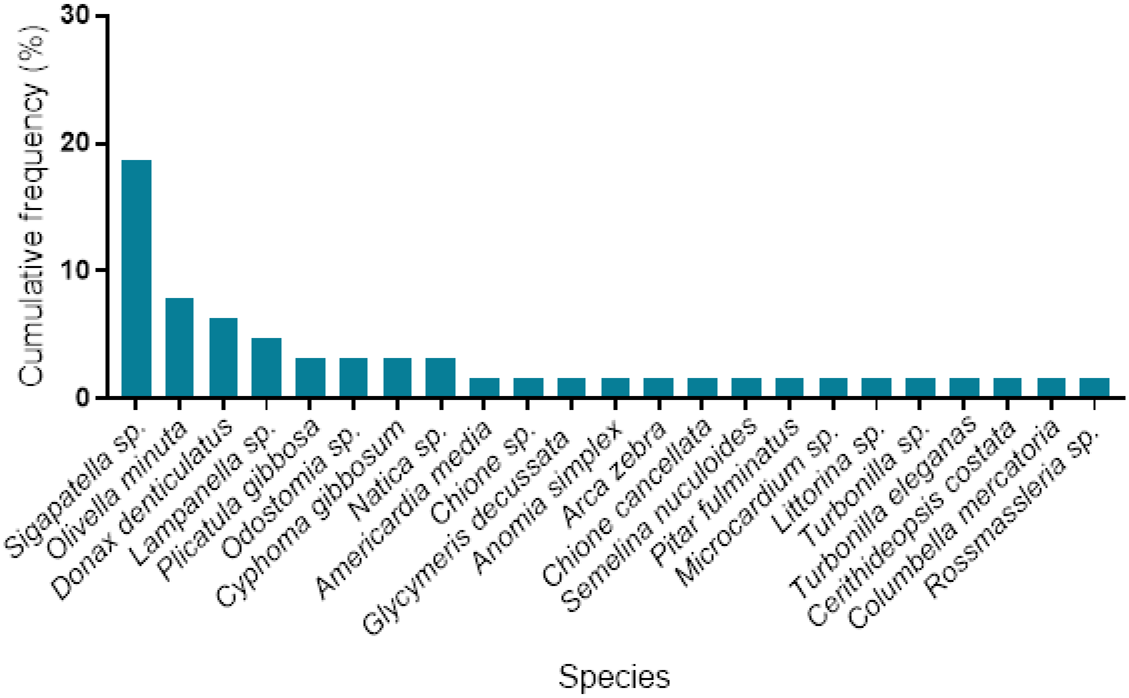

Figure 17. Cumulative frequency (%) of shell-mollusks at El Combate, Cabo Rojo, on August 26, 2016 (n=4).

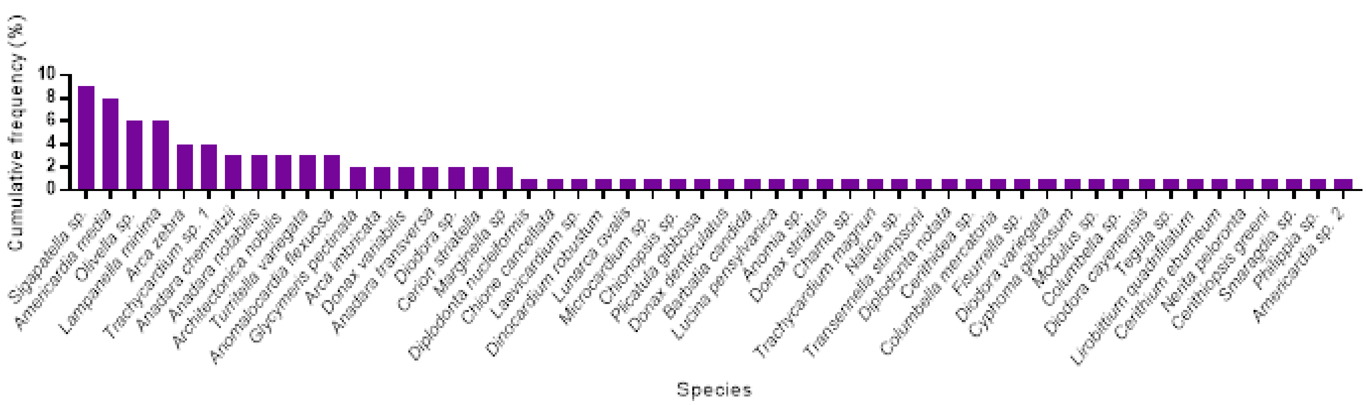

Figure 18. Cumulative frequency (%) of shell-mollusks at El Combate, Cabo Rojo, on October 21, 2016 (n=4).

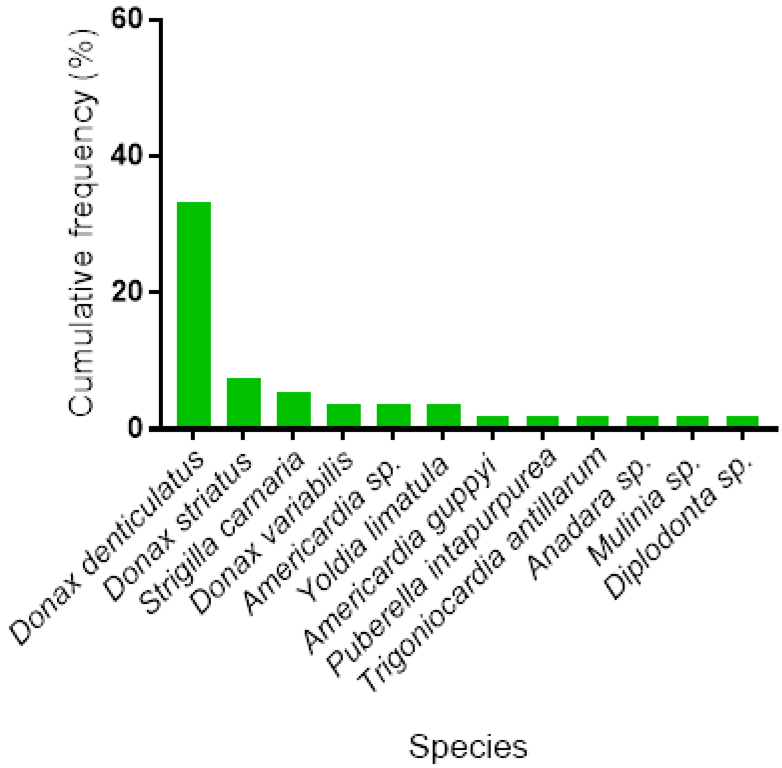

Figure 19. Cumulative frequency (%) of shell-mollusks at Mayagüez on September 2, 2016 (n=4).

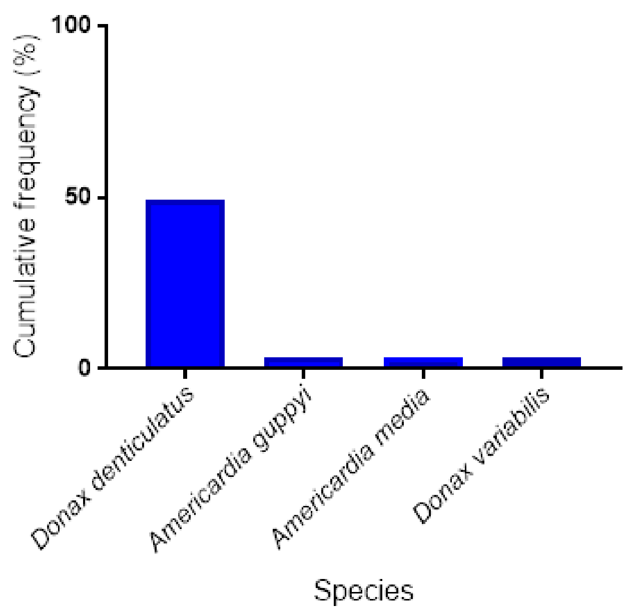

Figure 20. Cumulative frequency (%) of shell-mollusks at Mayagüez beach on November 18, 2016 (n=4).

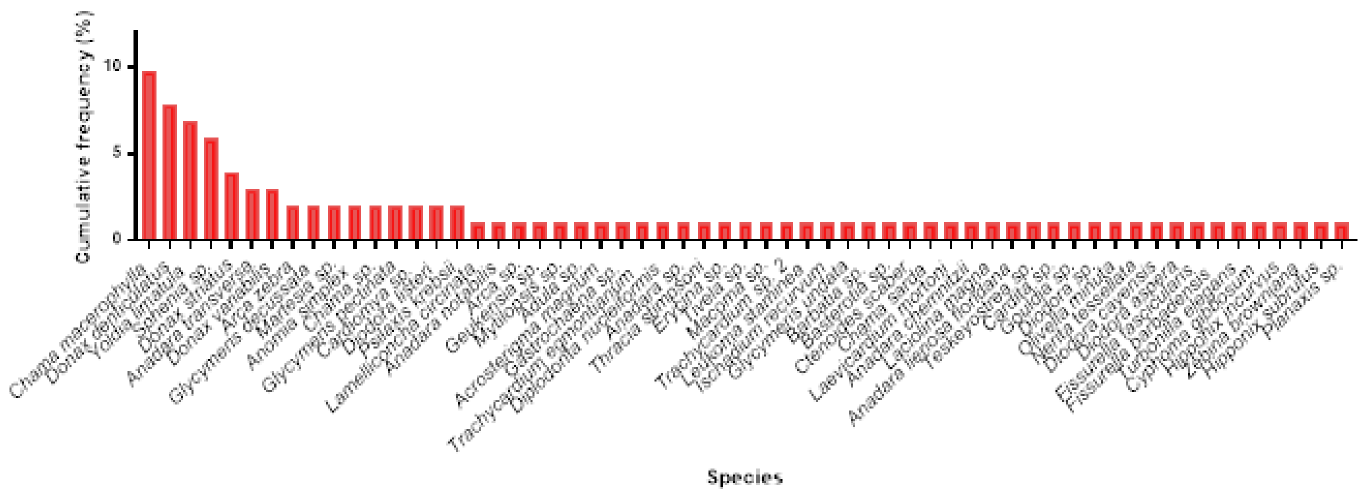

Figure 21. Cumulative frequency (%) of shell-mollusks at Añasco beach on August 31, 2016 (n=4).

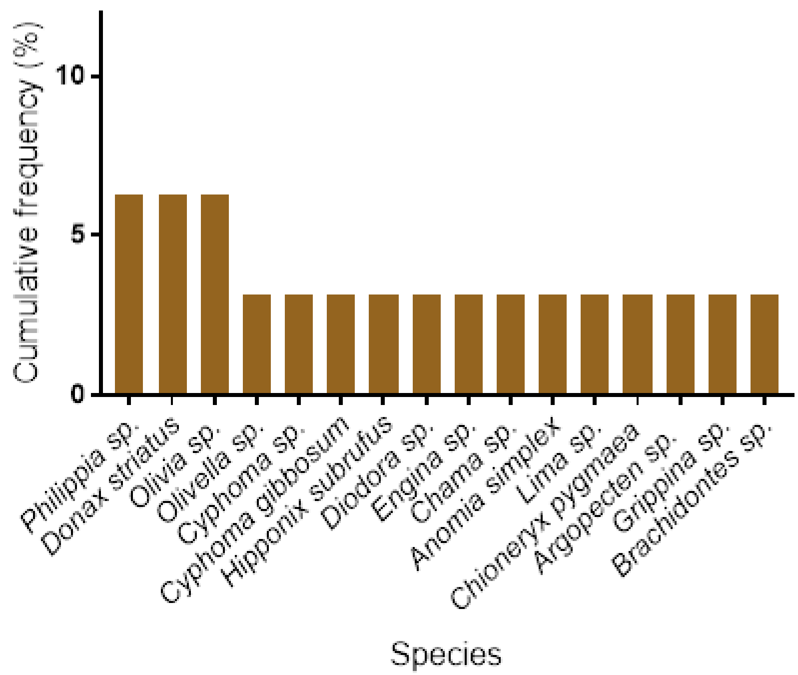

Figure 22. Cumulative frequency (%) of shell-mollusks at Córcega, Rincón, on September 16, 2016 (n=4).

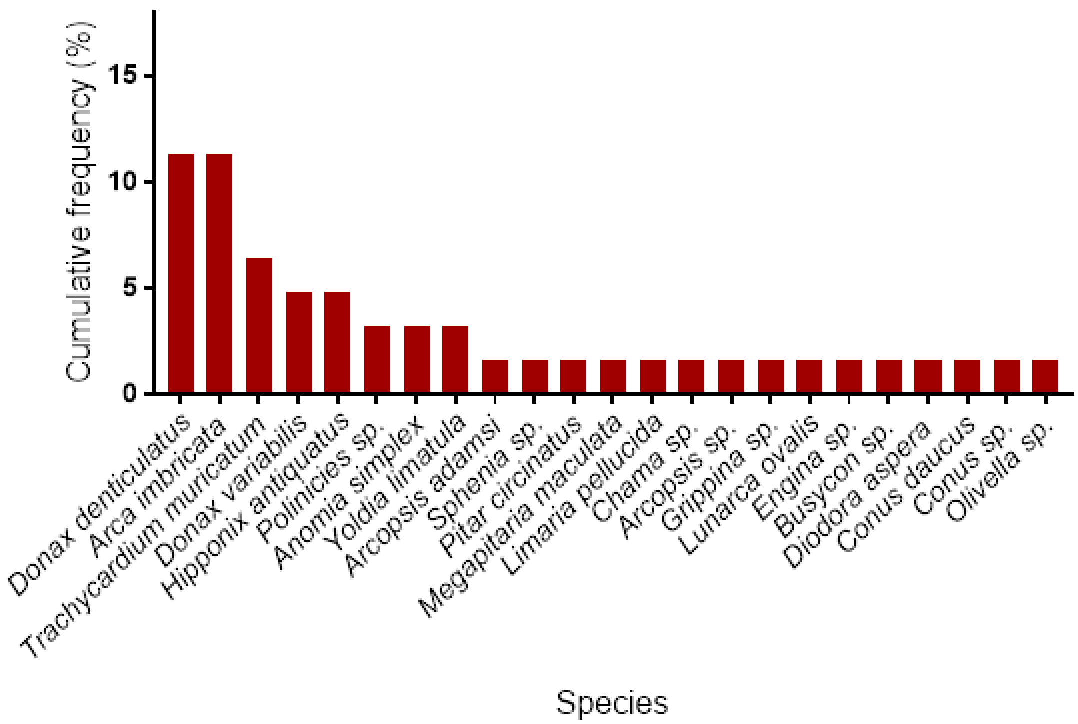

Figure 23. Cumulative frequency (%) of shell-mollusks at Añasco beach on October 15, 2016 (n=4).

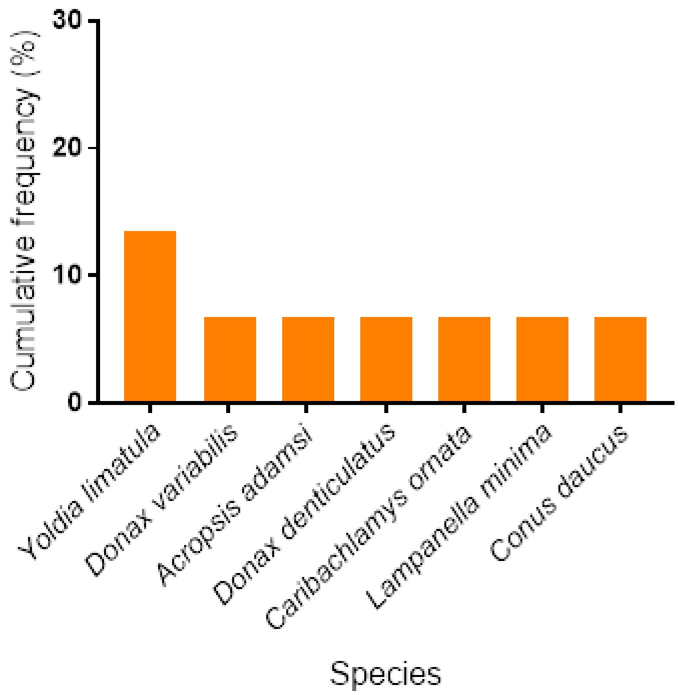

Figure 24. Cumulative frequency (%) of shell-mollusks at Córcega, Rincón, on November 4, 2016 (n=4).

Species of bivalves that were found in Cabo Rojo and Añasco during sampling 1 (August/September 2016) were *Arca zebra, Donax denticulatus, Glycymeris decussata* and *Anomia simplex*, while gastropods that were shared by these two beaches were *Olivella minuta, Turbonilla elegans* and *Cyphoma gibbosum* (see Table 10). Cabo Rojo and Rincón beaches shared one species of bivalve (*Anomia simplex*) and one species of gastropod (*Cyphoma gibbosum*). Cabo Rojo and Mayagüez beaches shared one bivalve (*Donax denticulatus*) and no gastropods since samples from Mayagüez lacked gastropods. Also, Añasco and Rincón beaches shared two species of bivalves (*Donax striatus* and *Anomia simplex*) and four species of gastropods (*Psilaxis krebsi, Cyphoma gibbosum, Hipponix subrufus* and *Diodora sp.*). Añasco and Mayagüez shared three species of bivalves (*Donax denticulatus, D. variabilis* and *Yoldia *limatula*). Furthermore, Rincón and Mayagüez beaches shared one species of bivalves *(Donax striatus*) and no gastropods since samples from Mayagüez lacked them.

During sampling 2 (October/ November 2016) (see Table 11) Cabo Rojo and Añasco beaches shared six species of bivalves (*Arca imbricata, Donax denticulatus, Trachycardium muricatum, Donax variabilis, Chama sp*. and *Anadara ovalis*) and one species of gastropod (*Olivella sp*.) Cabo Rojo and Rincón beaches shared two species of bivalves (*Donax denticulatus* and *D. variabilis*) and one species of gastropods (*Lampanella minima*). Cabo Rojo and Mayagüez beaches shared three species of bivalves (*Donax denticulatus, variabilis* and *Americardia media*) and no gastropods. Añasco and Rincón beaches shared two species of bivalves (*Donax denticulatus* and *D. variabilis*) and one species of gastropods (*Conus daucus*). Añasco and Mayagüez beaches shared two species of bivalves *(Donax denticulatus* and *D. variabilis*) and no species of gastropods. Moreover, Rincón and Mayagüez beaches shared two species of bivalves (*Donax denticulatus* and *variabilis*) and no gastropods (Table 11).

When species composition was compared in a cross-fashion, meaning that fauna collected from different beaches and from different samplings (i.e. Beach A in sampling 1 versus Beach B in sampling 2), the comparison between Cabo Rojo (sampling 1) versus Añasco (sampling 2) showed two shared species of bivalves (*Donax denticulatus* and *Anomia simplex*) and no gastropod species. Cabo Rojo (sampling 1) versus Rincón (sampling 2) shared one species of bivalves (*Donax denticulatus*) and no gastropod species. Meanwhile, Cabo Rojo (sampling 1) versus Mayagüez (sampling 2) shared one species of bivalves (*Donax denticulatus*) and no gastropods (Tables 10-11). Añasco (sampling 1) versus Rincón (sampling 2) shared two species of bivalves (*Donax denticulatus* and *variabilis*) and no gastropod species, and Añasco (sampling 1) versus Mayagüez (sampling 2) shared the same two species of bivalves (*Donax* *denticulatus* and *variabilis*) but no gastropod species. Moreover, Rincón (sampling 1) versus Mayagüez (sampling 2) did not share mollusks species (Tables 10-11).

Table 10. Jaccard indexes comparing composition of shell-mollusks between sites (beaches) in sampling 1.

Beach Comparison	Sampling 1 (August/September, 2016)		
Cabo Rojo versus Añasco	Group	J=C/(A+B+C)	J=C/(A+B-C)
	Gastropoda	0.10	0.17
	Bivalvia	0.07	0.09
	Both	0.08	0.11
Cabo Rojo versus Rincón	Group	J=C/(A+B+C)	J=C/(A+B-C)
	Gastropoda	0.05	0.06
	Bivalvia	0.05	0.06
	Both	0.05	0.06
Cabo Rojo versus Mayagüez	Group	J=C/(A+B+C)	J=C/(A+B-C)
	Gastropoda	0	0
	Bivalvia	0.04	0.05
	Both	0.03	0.03
Añasco versus Rincón	Group	J=C/(A+B+C)	J=C/(A+B-C)
	Gastropoda	0.08	0.12
	Bivalvia	0.07	0.10
	Both	0.07	0.10
Añasco versus Mayagüez	Group	J=C/(A+B+C)	J=C/(A+B-C)
	Gastropoda	0	0
	Bivalvia	0.05	0.06
	Both	0.04	0.04
Rincón versus Mayagüez	Gastropoda	0	0
	Bivalvia	0.05	0.06
	Both	0.03	0.04
	Gastropoda	0	0

Table 11. Jaccard indexes comparing composition of shell-mollusks between sites (beaches) in sampling 2.

Beach Comparison	Sampling 2 (October/November, 2016)		
Cabo Rojo versus Añasco	Group	J=C/(A+B+C)	J=C/(A+B-C)
	Gastropoda	0.03	0.03
	Bivalvia	0.12	0.25
	Both	0.09	0.15
Cabo Rojo versus Rincón	Group	J=C/(A+B+C)	J=C/(A+B-C)
	Gastropoda	0.03	0.04
	Bivalvia	0.06	0.08
	Both	0.05	0.06
Cabo Rojo versus Mayagüez	Group	J=C/(A+B+C)	J=C/(A+B-C)
	Gastropoda	0	0
	Bivalvia	0.09	0.14
	Both	0.05	0.06
Añasco versus Rincón	Group	J=C/(A+B+C)	J=C/(A+B-C)
	Gastropoda	0.08	0.12
	Bivalvia	0.09	0.14
	Both	0.09	0.14
Añasco versus Mayagüez	Group	J=C/(A+B+C)	J=C/(A+B-C)
	Gastropoda	0	0
	Bivalvia	0.09	0.15
	Both	0.07	0.09
Rincón versus Mayagüez	Group	J=C/(A+B+C)	J=C/(A+B-C)
	Gastropoda	0	0
	Bivalvia	0.18	0.67
	Both	0.15	0.40

The Shannon-Wiener Index (D) analysis for the shell mollusks in the four beaches is presented in Table 12. The Shannon-Wiener diversity was directly related to the number of species. The abundance and species richness of the molluscs varied significantly among the beaches.

Mean sorting values did not vary much and the resulting range or scale was very small (Figures 25-26). There was not a significant correlation between sediment sorting and mollusk diversity (Shannon Wiener, D; Figures 25-26). There was not a significant correlation between mean particle grain size and shell-mollusk biodiversity (Figures 27-28). However, mean sorting values lower than 1.35 and greater than 1.55 were related to higher biodiversity indices (Shannon-Wienner Index, D). In Añasco beach, the D-values for shell mollusks (gastropods with 2.67 and bivalves with 3.45) were relatively high during sampling 1 (August/September 2016) and this locality had among the lowest sorting values. Samples from Rincón and Mayagüez showed that the diversity of bivalves and gastropods remained constant regardless of the sorting during sampling 1.

Table 12. Shannon-Wiener Index (D) analysis of shell-mollusks for the selected beaches during both samplings (year 2016). Effective richness (lnD) in given in paretheses.

Beach	Sampling 1 (August/September)			Sampling 2 (October/November)		
	Gastropods	Bivalves	Both	Gastropods	Bivalves	Both
El Combate, Cabo Rojo	2.59 (13)	2.24 (9)	2.05 (8)	2.83 (17)	3.08 (22)	3.65 (38)
Córcega, Rincón	2.02 (7)	2.04 (8%)	2.72 (15)	0.69 (2)	1.56 (5)	1.91 (7)
Balneario Tres Hermanos, Añasco	2.67 (31)	3.45 (14)	3.74 (42)	1.97 (7)	2.38 (11)	2.84 (17)
El Maní, Mayagüez	---------	1.47 (4)	1.47 (4)	---------	0.63 (2)	0.63 (2)

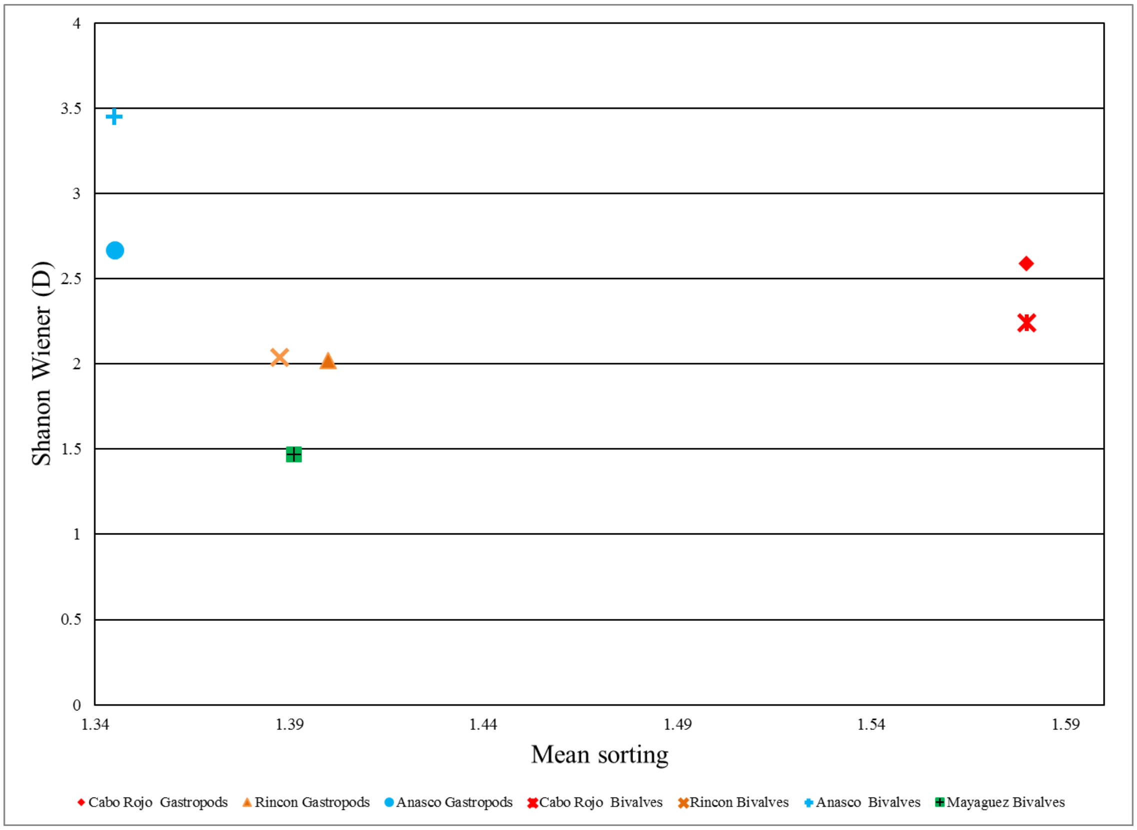

Figure 25. Shannon Wiener Index (D) versus mean sorting of sediment at the selected beaches during sampling 1 (August/September 2016). See table 6 for sorting values and categories.

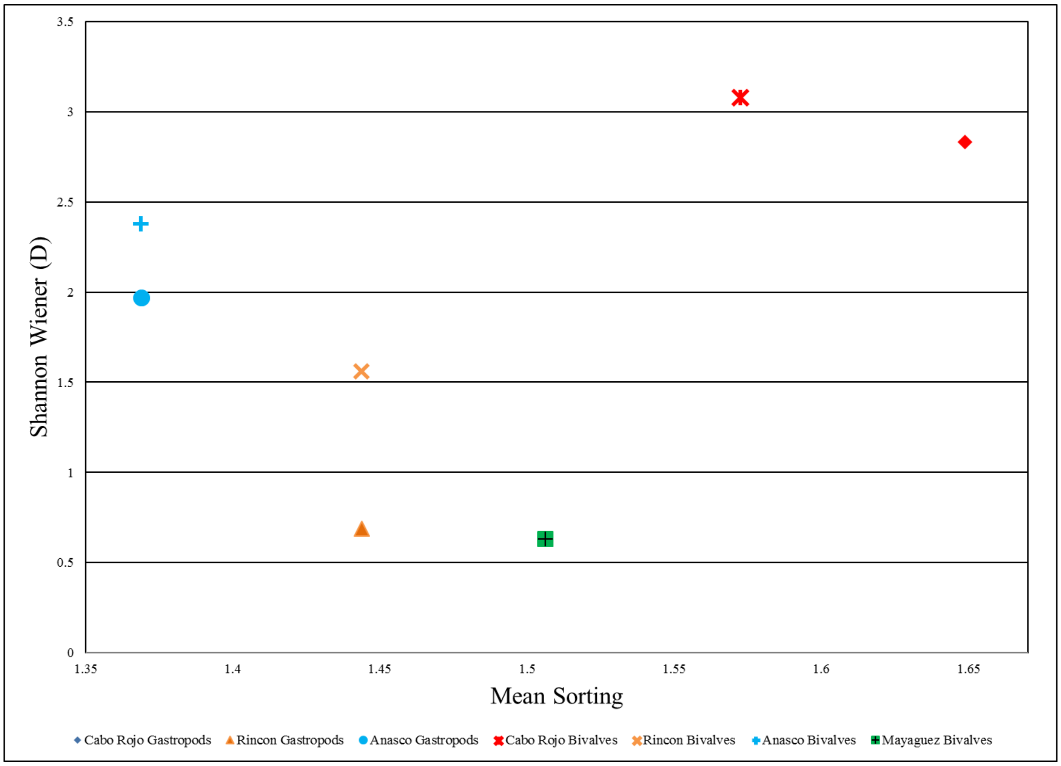

Figure 26. Shannon Wiener Index (D) versus mean sorting of sediment of the selected beaches during sampling 2 (October/November 2016). See table 6 for sorting values and categories.

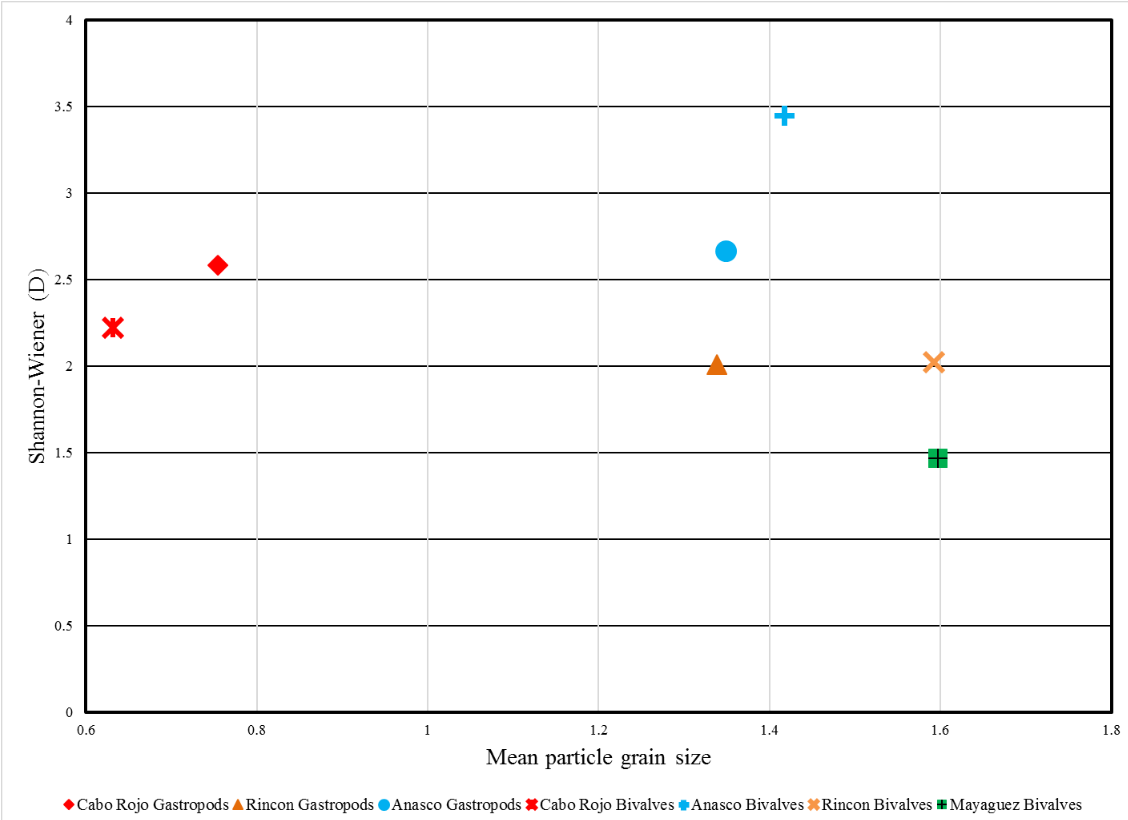

Figure 27. Shannon Wiener Index (D) versus mean particle grain size (ϕ) of sediment at the selected beaches during sampling 1 (August/September 2016). See table 5 for sand class and sand particle grain size (µm).

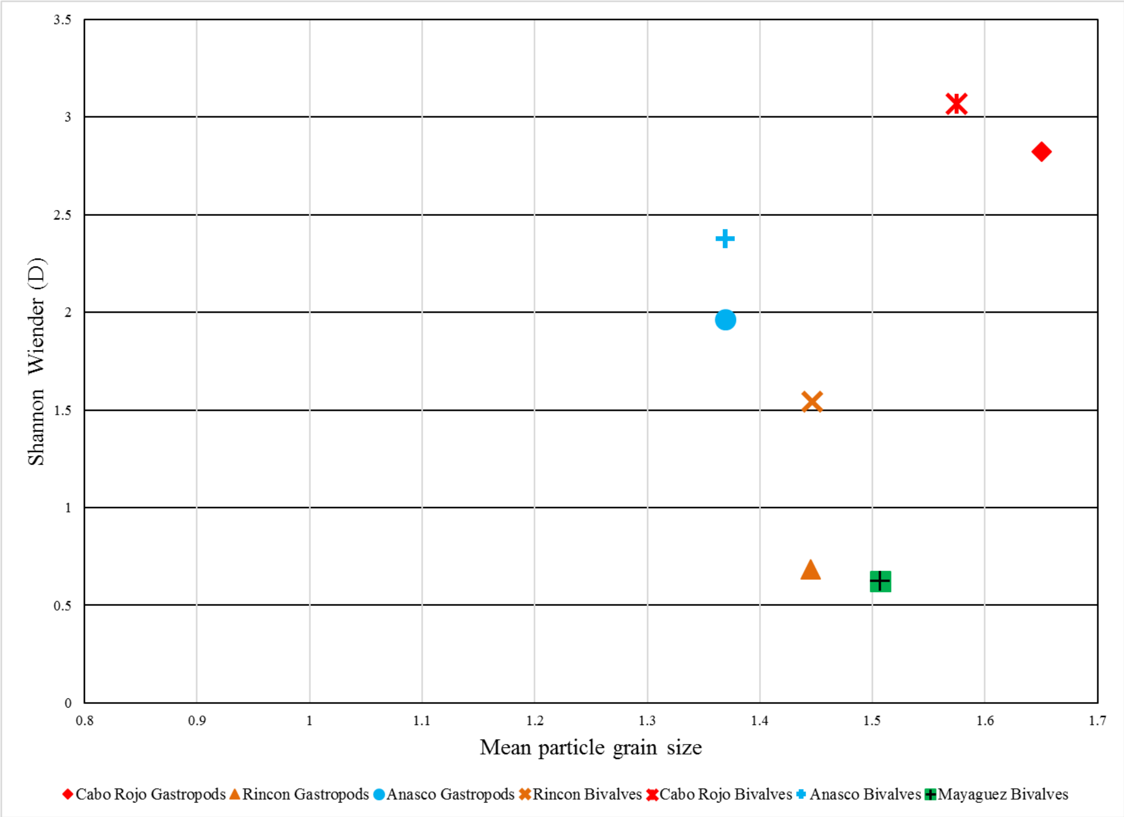

Figure 28. Shannon Wiener Index (D) versus mean particle grain size (***ϕ***) of sediment at the selected beaches during sampling 2 (October/November 2016). See table 5 for sand class and sand particle grain size (µm).

Abundance of bivalves and gastropods at the selected beaches

Mayagüez and Añasco beaches presented the highest abundance of bivalves on both sampling times (August/September and October/November, 2016) (Figure 29). Mean number of individuals per time showed that El Combate beach presented the highest abundance of gastropods on both samplings (Figure 30). Mollusk abundances were analyzed according to the variables time (sampling 1 versus sampling 2), transect (T1, T2, T3, T4), zone (sand versus aquatic) and locality (beaches). ANOVA and Tukey tests showed significance differences for bivalves in the variables of time (samplings), transect and zone ($p > 0.05$) for Añasco beach. Therefore, the null hypothesis is rejected for bivalves in Añasco (Table 13). There were also significant differences in the variables of time and zone when it comes to the number of bivalves found at Cabo Rojo beach (Table 14). Cabo Rojo also showed significant differences in the abundance of gastropods at variable zone (Table 14). Mayagüez beach presented significant differences for the abundance of bivalves in the variables time and zone (Table 15). Rincón beach did not present significant differences in the number of bivalves but did in the number of gastropods for variable transect (p=0.0084) (Table 16).

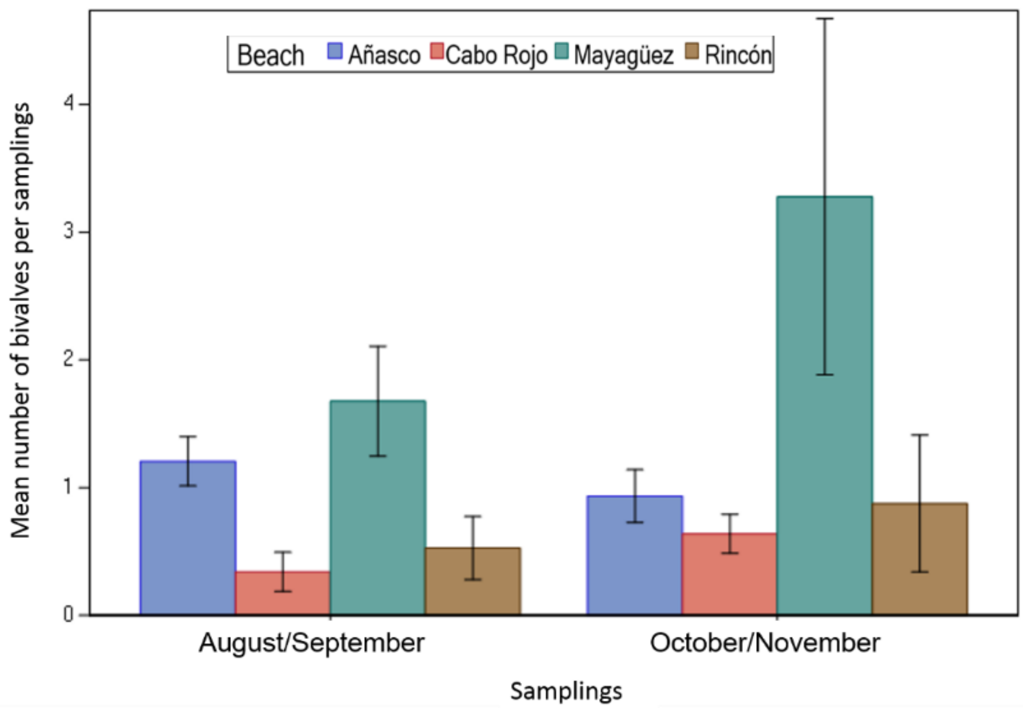

Figure 29. Mean number of bivalves per samplings at the selected beaches (transects combined)**.**

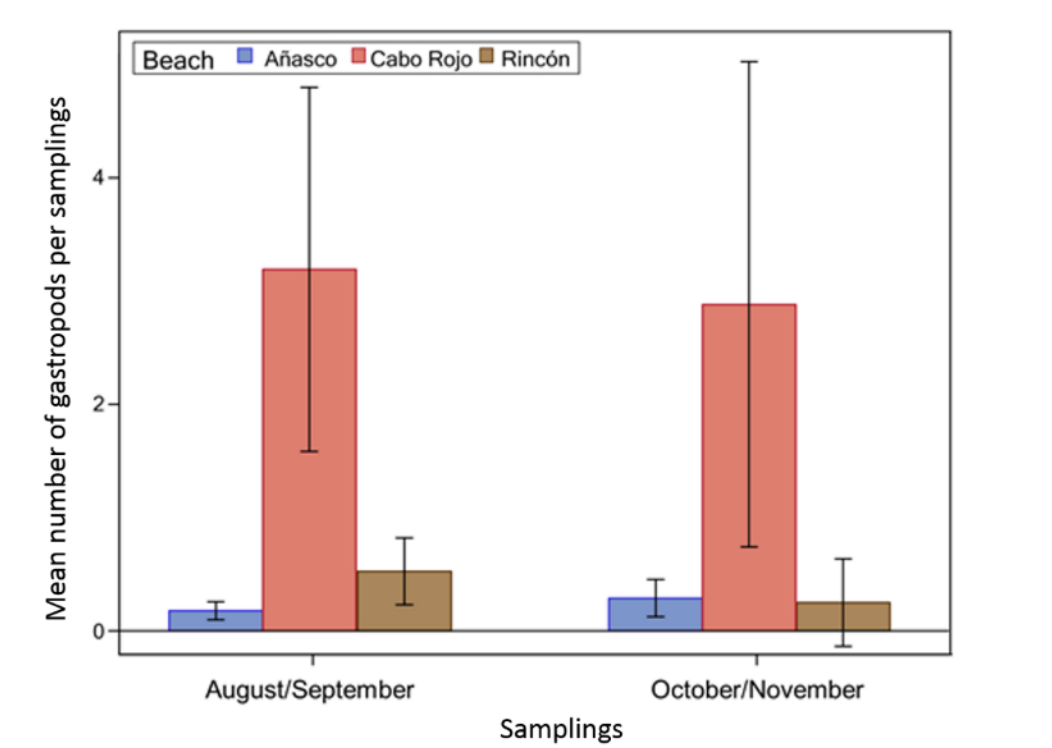

Figure 30. Mean number of gastropods per samplings at the selected beaches (transects combined).

Table 13. ANOVA (SC type III) for the abundance [Log(x+1)] of bivalves and gastropods in Añasco beach, according to the variables time (sampling), transect and zone (sand vs. aquatic). N= 48. Red p-values represent significant differences (α<0.05). CV=55.55 % (Bivalvia[Log(x+1)]), CV=131.32% (Gastropoda[Log(x+1)])

		Bivalvia				**Gastropoda**			
Source	d.f.	SS	MS	F	p-value	SS	MS	F	p-value
Model	5	2.79	0.56	7.07	0.0001	0.18	0.04	0.82	0.5428
Time	1	1.15	1.15	14.62	0.0004	0.02	0.02	0.47	0.4984
Transect	3	1.05	0.35	4.45	0.0084	0.15	0.05	1.15	0.3420
Zone	1	0.58	0.58	7.38	0.0095	0.01	0.01	0.20	0.6604
Error	42	3.32	0.08			1.88	0.04		
Total	47	6.11							

Table 14. ANOVA (SC type III) for the abundance [Log(x+1)] of bivalves and gastropods in Cabo Rojo beach, according to the variables time (sampling), transect and zone (sand vs. aquatic). N= 48. Red p-values represent significant differences (α < 0.05). CV=70.12% (Bivalvia[Log(x+1)]), CV=95.87% (Gastropoda[Log(x+1)])

		Bivalvia				**Gastropoda**			
Source	d.f.	SS	MS	F	p-value	SS	MS	F	p-value
Model	5	2.34	0.47	9.41	<0.0001	4.07	0.81	2.95	0.0228
Time	1	0.95	0.95	19.04	0.0001	0.24	0.24	0.86	0.3601
Transect	3	0.30	0.10	2.01	0.1271	1.77	0.59	2.13	0.1103
Zone	1	1.09	1.09	21.96	<0.0001	2.06	2.06	7.48	0.0091
Error	42	2.09	0.05			11.59	0.28		
Total	47	4.43				15.65			

Table 15. ANOVA (SC type III) for the abundance [Log(x+1)] of bivalves in Mayagüez beach, according to the variables time (sampling), transect and zone (sand vs. aquatic). N= 48. Red p-values represent significant differences (α < 0.05). CV=87.75% (Bivalvia[Log(x+1)])

Source	d.f.	SS	MS	F	p-value
Model	5	1.34	0.27	3.59	0.0086
Time	1	0.39	0.39	5.23	0.0273
Transect	3	0.01	1.7E-03	0.02	0.9953
Zone	1	0.95	0.95	12.65	0.0009
Error	42	3.14	0.07		
Total	47	4.49			

Table 16. ANOVA (SC type III) for the abundance [Log(x+1)] of bivalves and gastropods in Rincón beach, according to the variables time (sampling), transect and zone (sand vs. aquatic). N= 48. Red p-values represent significant differences ($\alpha < 0.05$). CV=190.19% (Bivalvia[Log(x+1)]), CV=227.76% (Gastropoda[Log(x+1)])

		Bivalvia				**Gastropoda**			
Source	d.f.	SS	MS	F	p-value	SS	MS	F	p-value
Model	5	0.16	0.03	0.85	0.5226	0.32	0.06	3.32	0.0129
Time	1	0.02	0.02	0.54	0.4672	0.06	0.06	3.22	0.0799
Transect	3	0.10	0.03	0.88	0.4587	0.26	0.09	4.45	0.0084
Zone	1	0.04	0.04	1.07	0.3074	6.5E-04	6.5E-04	0.03	0.8561
Error	42	1.63	0.04			0.82	0.02		
Total	47	1.79				1.14			

Means for the abundance of bivalves were significantly (p> 0.05) different between samplings for Añasco beach (Table 17), for Combate beach (Table 18), and for Mayagüez beach (Table 19). On the other hand, Rincón did not show differences in abundance between samplings for either group of mollusks (Table 20).

Table 17. Tukey Test for the abundance [Log(x+1)] of bivalves and gastropods in Añasco beach, according to time (sampling; year 2016). Different letters represent significant differences (*; $\alpha > 0.05$). Error: 0.0789(Bivalvia[Log(x+1)]) and Error: 0.0447(Gastropoda[Log(x+1)]).

	Bivalvia				**Gastropoda**		
Time	d.f.	Means	n	S.E.	Means	n	S.E.
October/November	42	0.35	24	0.06 A*	0.14	24	0.04 A
August/September	42	0.66	24	0.06 B*	0.18	24	0.04 A

Table 18. Tukey Test for the abundance [Log(x+1)] of bivalves and gastropods in Cabo Rojo beach, according to time (sampling; year 2016). Different letters represent significant differences (*; α > 0.05). Error: 0.0498(Bivalvia[Log(x+1)]) and Error:0.2759(Gastropoda[Log(x+1)]).

	Bivalvia				**Gastropoda**		
Time	d.f.	Means	n	S.E.	Means	n	S.E.
August/September	42	0.18	24	0.05 A*	0.48	24	0.11 A
October/November	42	0.46	24	0.05 B*	0.62	24	0.11 A

Table 19. Tukey Test for the abundance [Log(x+1)] of bivalves in Mayagüez beach, according to time (sampling; year 2016). Different letters represent significant differences (*; α > 0.05). Error: 0.0749(Bivalvia[Log(x+1)]).

	Bivalvia			
Time	d.f.	Means	n	S.E.
August/September	42	0.17	24	0.05 A*
October/November	42	0.47	24	0.05 B*

Table 20. Tukey Test for the abundance [Log(x+1)] of bivalves and gastropods in Rincón beach, according to time (sampling; year 2016). Different letters represent significant differences (*; α > 0.05). Error: 0.0387(Bivalvia[Log(x+1)]) and Error:0.0194(Gastropoda[Log(x+1)]).

	Bivalvia				**Gastropoda**		
Time	d.f.	Means	n	S.E	Means	n	S.E
August/September	42	0.08	24	0.04 A	0.03	24	0.03 A
October/November	42	0.12	24	0.04 A	0.10	24	0.03 A

The mean number of bivalves per zone (seasons combined) increased from sand to the aquatic zone more markedly for Mayagüez and Combate (Cabo Rojo) than in the other two localities (Figure 31). Meanwhile, the mean number of gastropods per zone (seasons combined) decreased from the aquatic to the sand zone, much more pronounced for Cabo Rojo beach. Samples from Mayagüez rendered no gastropods during this study (Figure 32).

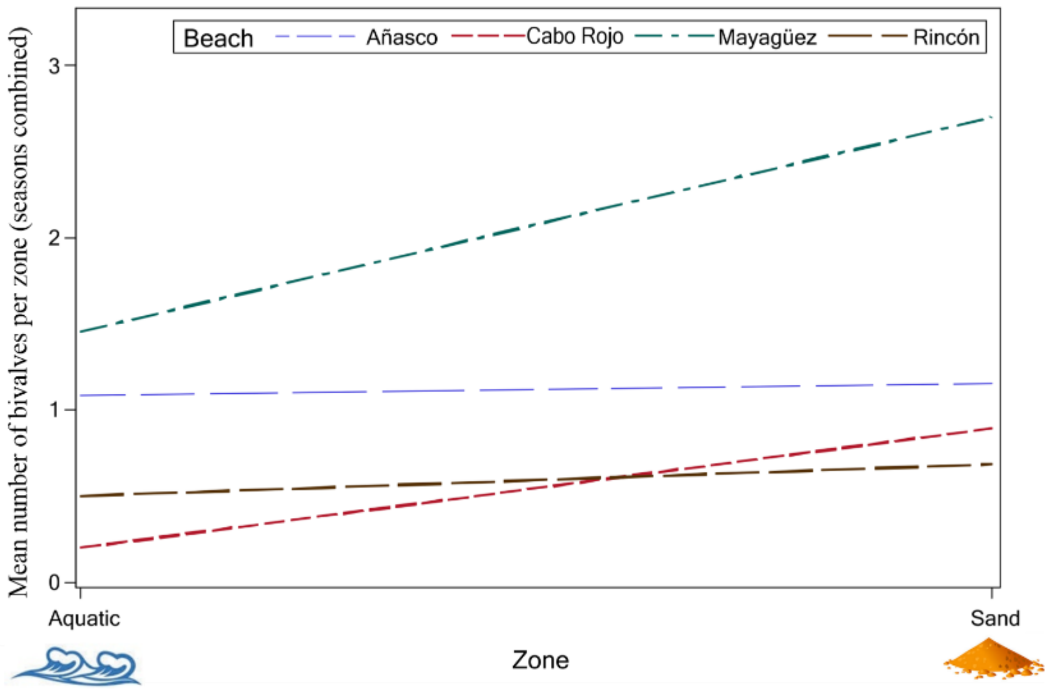

Figure 31. Mean number of bivalves per zone (seasons combined) found at the selected beaches.

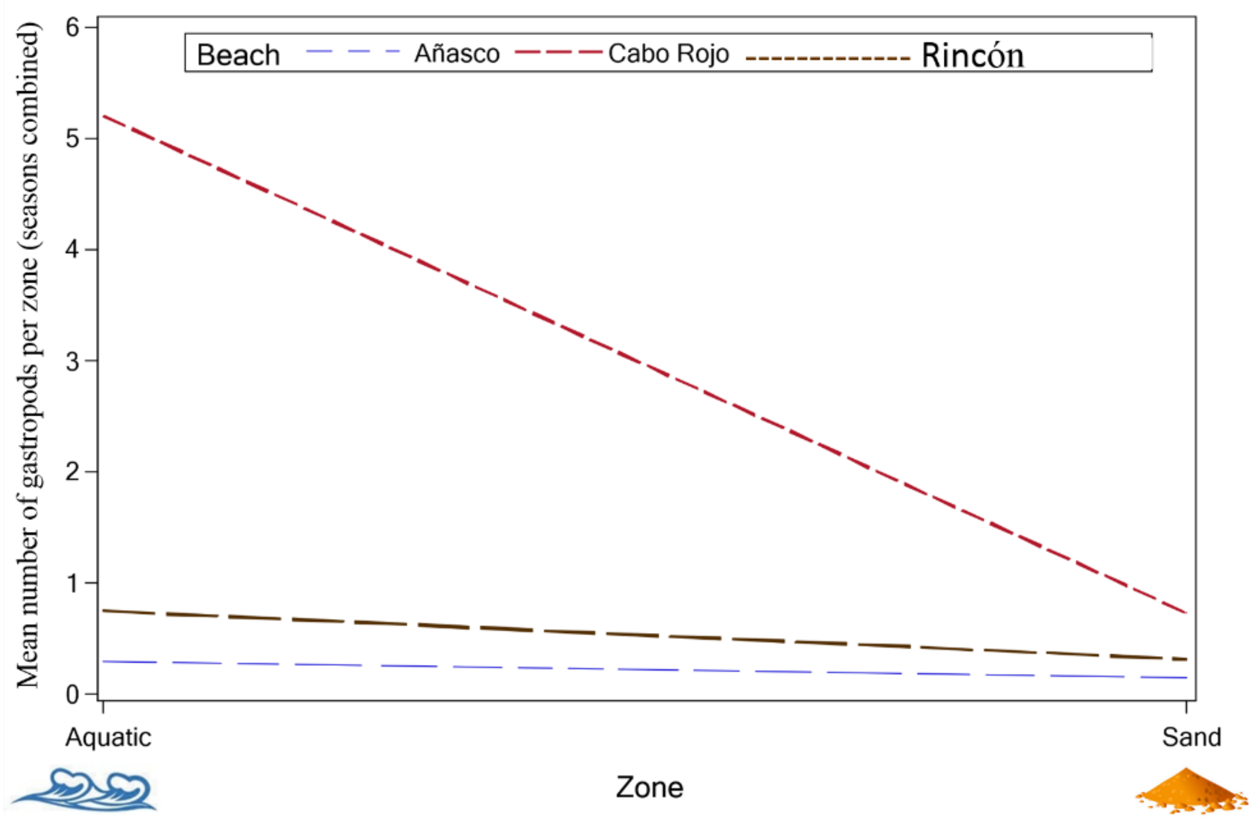

Figure 32. Mean number of gastropods per zone (seasons combined) found at the selected beaches.

In addition, there were significant differences in the number of bivalves found in the different habitats (sand vs aquatic) for Añasco; therefore, the null hypothesis is rejected for this particular group in this beach (Table 21). Similarly, when comparing the different habitats (sand versus aquatic) in Cabo Rojo there were also significant differences between the number of bivalves and gastropods (Table 22), as well as in the quantity of bivalves at Mayagüez beach (Table 23). Finally, there were no significant differences between zones (sand versus aquatic) for the abundance of neither group in Rincón (Table 24).

Table 21. Tukey Test for the abundance [Log(x+1)] of bivalves and gastropods in Añasco beach in 2016, according to the variable zone (sand versus aquatic). Different letters represent significant differences (*; α > 0.05). Error: 0.0789(Bivalvia[Log(x+1)]) and Error: 0.0447(Gastropoda[Log(x+1)]).

	Bivalvia				Gastropoda		
Zone	d.f.	Means	n	S.E	Means	n	S.E
aquatic	42	0.40	24	0.06 A*	0.15	24	0.04 A
sand	42	0.62	24	0.06 B*	0.17	24	0.04 A

Table 22. Tukey Test for the abundance [Log(x+1)] of bivalves and gastropods in Cabo Rojo beach in 2016, according to the variable zone (sand versus aquatic). Different letters represent significant differences (*; α > 0.05). Error: 0.0498(Bivalvia[Log(x+1)]) and Error: 0.2759(Gastropoda[Log(x+1)]).

	Bivalvia				Gastropoda		
Zone	d.f.	Means	n	S.E.	Means	n	S.E.
aquatic	42	0.17	24	0.05 A*	0.34	24	0.11 A*
sand	42	0.47	24	0.05 B*	0.76	24	0.11 B*

Table 23. Tukey Test for the abundance [Log(x+1)] of bivalves in Mayagüez beach in 2016, according to the variables zone (sand versus aquatic). Different letters represent significant differences (*; α > 0.05). Error: 0.0749(Bivalvia[Log(x+1)]).

	Bivalvia			
Zone	d.f.	Means	n	S.E.
sand	42	0.17	24	0.06 A*
aquatic	42	0.45	24	0.06 B*

Table 24. Tukey Test for the abundance [Log(x+1)] of bivalves and gastropods in Rincón beach in 2016, according to the variable zone (sand versus aquatic). Different letters represent significant differences (*; α > 0.05). Error: 0.0498(Bivalvia[Log(x+1)]) and Error: 0.2759(Gastropoda[Log(x+1)]).

	Bivalvia				Gastropoda		
Zone	d.f.	Means	n	S.E.	Means	n	S.E.
aquatic	42	0.07	24	0.04 A	0.06	24	0.03 A
sand	42	0.13	24	0.04 A	0.06	24	0.03 A

When the mean number of bivalves and gastropods were compared among transects (T1-T4) within localities (Tables 25-28), no significant differences were obtained in Cabo Rojo and Mayagüez.

Table 25. Tukey Test for the abundance [Log(x+1)] of bivalves and gastropods in Añasco beach in 2016, according to the variable transect. Different letters represent significant differences (*; α > 0.05). Error:0.0789(Bivalvia[Log(x+1)]) and Error:0.0447(Gastropoda[Log(x+1)]).

	Bivalvia				Gastropoda		
Transect	d.f.	Means	n	S.E.	Means	n	S.E.
T1	42	0.32	12	0.08 A B	0.06	12	0.06 A
T2	42	0.46	12	0.08 A B	0.18	12	0.06 A
T3	42	0.52	12	0.08 A B	0.20	12	0.06 A
T4	42	0.73	12	0.08 B	0.20	12	0.06 A

Table 26. Tukey Test for the abundance [Log(x+1)] of bivalves and gastropods in Cabo Rojo beach in 2016, according to the variable transect. Different letters represent significant differences (*; α > 0.05). Error: 0.0498(Bivalvia[Log(x+1)]) and Error: 0.2759(Gastropoda[Log(x+1)]).

	Bivalvia				Gastropoda		
Transect	d.f.	Means	n	S.E.	Means	n	S.E.
T1	42	0.21	12	0.06A	0.24	12	0.15A
T2	42	0.28	12	0.06A	0.55	12	0.15A
T3	42	0.36	12	0.06A	0.65	12	0.15A
T4	42	0.42	12	0.06A	0.75	12	0.15A

Table 27. Tukey Test for the abundance [Log(x+1)] of bivalves in Mayagüez beach in 2016, according to the variable transect. Different letters represent significant differences (*; α > 0.05). Error: 0.0749(Bivalvia[Log(x+1)]).

	Bivalvia			
Transect	d.f.	Means	n	S.E.
T1	42	0.30	12	0.08A
T2	42	0.30	12	0.08A
T3	42	0.31	12	0.08A
T4	42	0.33	12	0.08A

Table 28. Tukey Test for the abundance [Log(x+1)] of bivalves and gastropods in Rincón beach in 2016, according to the variable transect. Different letters represent significant differences (*; α > 0.05).

	Bivalvia				Gastropoda		
Transect	d.f.	Means	n	S.E.	Means	n	S.E.
T1	42	0.03	12	0.06A	0.00	12	0.04A
T2	42	0.12	12	0.06A	0.00	12	0.04A
T3	42	0.13	12	0.06A	0.06	12	0.04A B*
T4	42	0.14	12	0.06A	0.18	12	0.04A B*

Correlation between the mean sorting, mean particles grain size and the abundance of mollusks

Although the mean sorting variations among the sediments in different locations was relatively small (Figures 33-34), there were no patterns observed in the correlation between abundance of mollusks and sorting, as seen for the sand zone on Figure 34: with a sorting value of less than 1.37, the abundance remained constant or decreased. Abundances changed for some locations and sampling periods when mean sorting had values above 1.37. However, when sorting was above 1.5 the abundances of gastropods and bivalves became constant again for most locations and sampling periods. Combate beach acted as an outlier, where an increase in sorting was related to an increment in the abundance of gastropods but only in the aquatic swash zone. The graphs that show the abundance of gastropods and bivalves in both samplings periods and both sampling locations along the beach (beach face versus aquatic swash zone) are in Appendix L (L1-L4).

Figures 35 and 36 show abundances of shell-mollusks and mean particle grain size changes did not show any relation. Grain sizes ranged from 125 (fine sand)-1000μm (coarse sand).

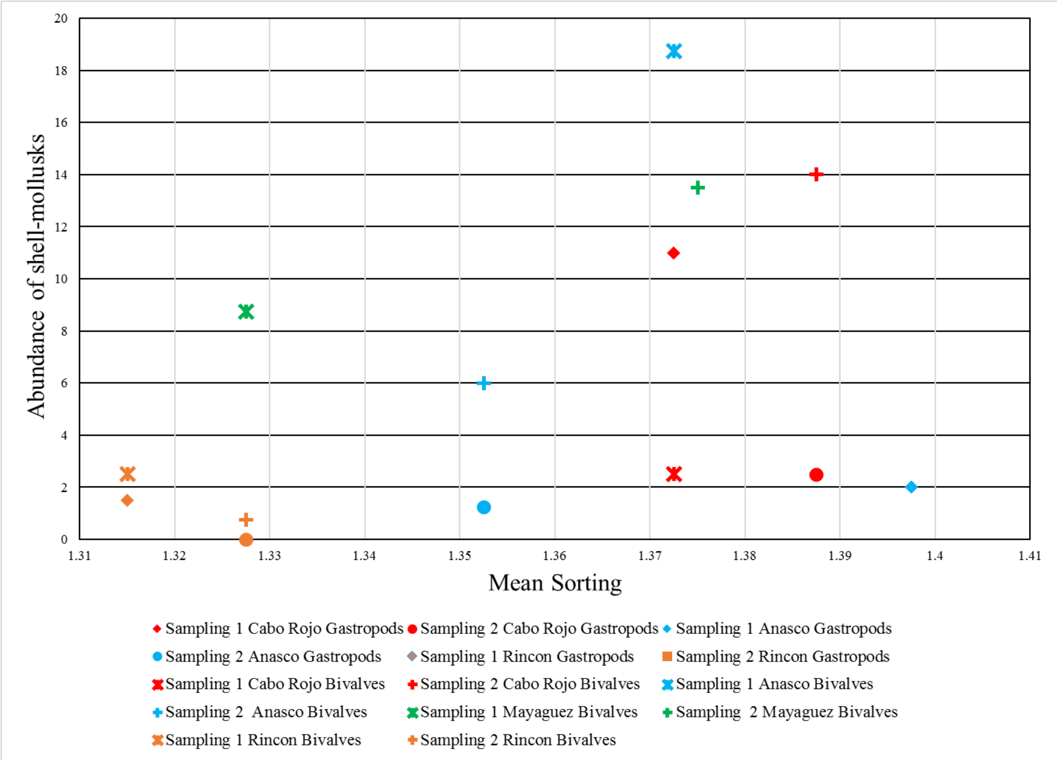

Figure 33. Abundance of gastropods (♦, ●) and bivalves (+, *) in the beach face sand zone in both sampling periods (August/September versus October/November, 2016) of the selected beaches (Cabo Rojo, Añasco, Rincón and Mayagüez). See table 6 for sorting values and categories.

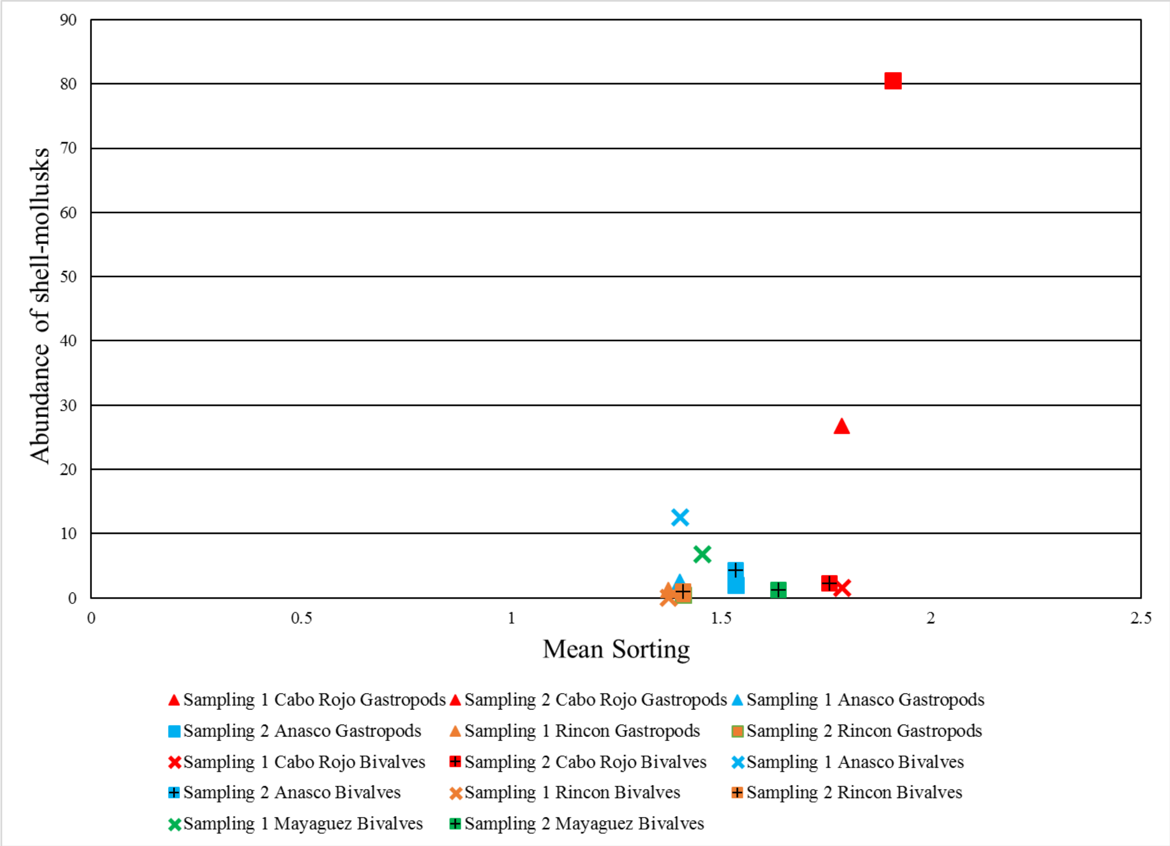

Figure 34. Abundance of gastropods (▲, ■) and bivalves (x, ◘) in the aquatic swash zone in both sampling periods (August/September versus October/November, 2016) of the selected beaches (Cabo Rojo, Añasco, Rincón and Mayagüez). See table 6 for sorting values and categories.

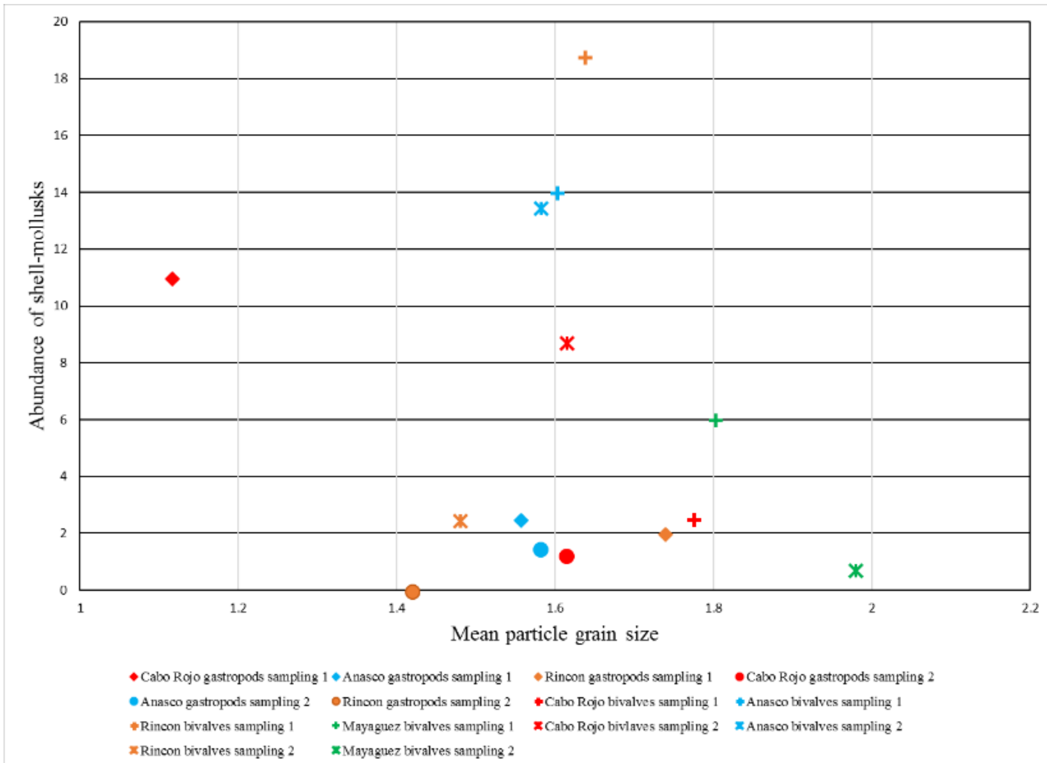

Figure 35. Abundance of gastropods (♦, ●) and bivalves (+, *) versus mean particle grain size in the beach face sand zone in both sampling periods (August/September versus October/November, 2016) of the selected beaches (Cabo Rojo, Añasco, Rincón and Mayagüez). See table 5 for sand class and sand particle grain size (µm).

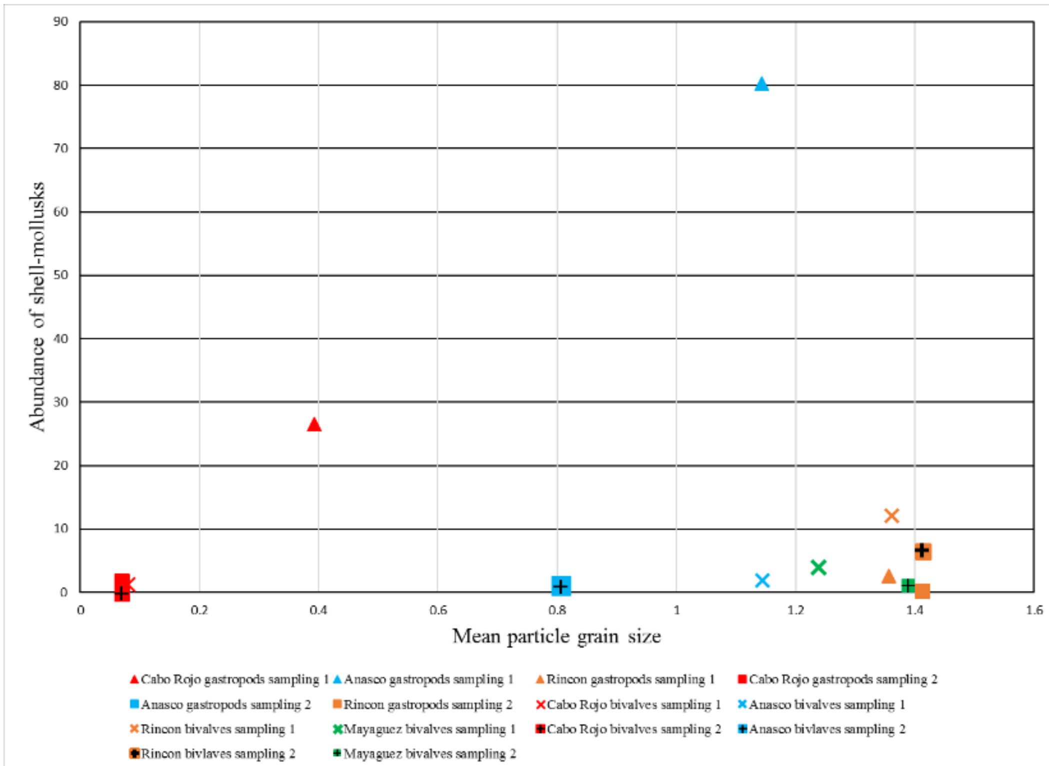

Figure 36. Abundance of gastropods (▲, ■) and bivalves (x, ◘) versus mean particle grain size in the aquatic swash zone in both sampling periods (August/September versus October/November, 2016) of the selected beaches (Cabo Rojo, Añasco, Rincón and Mayagüez). See table 5 for sand class and sand particle grain size (µm).

Correlation between the mean sorting, mean particle grain size and the cumulative species richness of mollusks

The substrate may influence the distribution, abundance and life habits of benthic and marine invertebrates and, thus, is a primary environmental parameter to understand (Alexander et al., 1993). As sorting (grain size) increased, the number of mollusks species that were found in the beach face sand zone at Rincón and Mayagüez during both samplings (August/September versus October/November) remained relatively constant. Figure 37 shows that as mean sorting increased from 1.34 to 1.41, the cumulative richness stayed the same. However, it is important to mention that mean sorting increase from 1.34 to 1.41 represents a very small change in sorting.

Figure 38 shows a variation in cumulative richness, but the sorting values did not change much (1.4-1.7). Again, sorting and cumulative richness of shell-mollusks do not seem related to each other but the changes in sorting are not large. All graphs on cumulative richness of gastropods and bivalves in both zones and both samplings at the selected beaches are at Appendix M (M1-M10).

The mean grain siz changes of the sediment particles did not show any relation to the cumulative richness of shell-mollusks were not related (Figures 39-40), same as the mean sorting mean sorting (combining both zones and samplings for each beach) relative to the cumulative richness of mollusk (Figure 41).

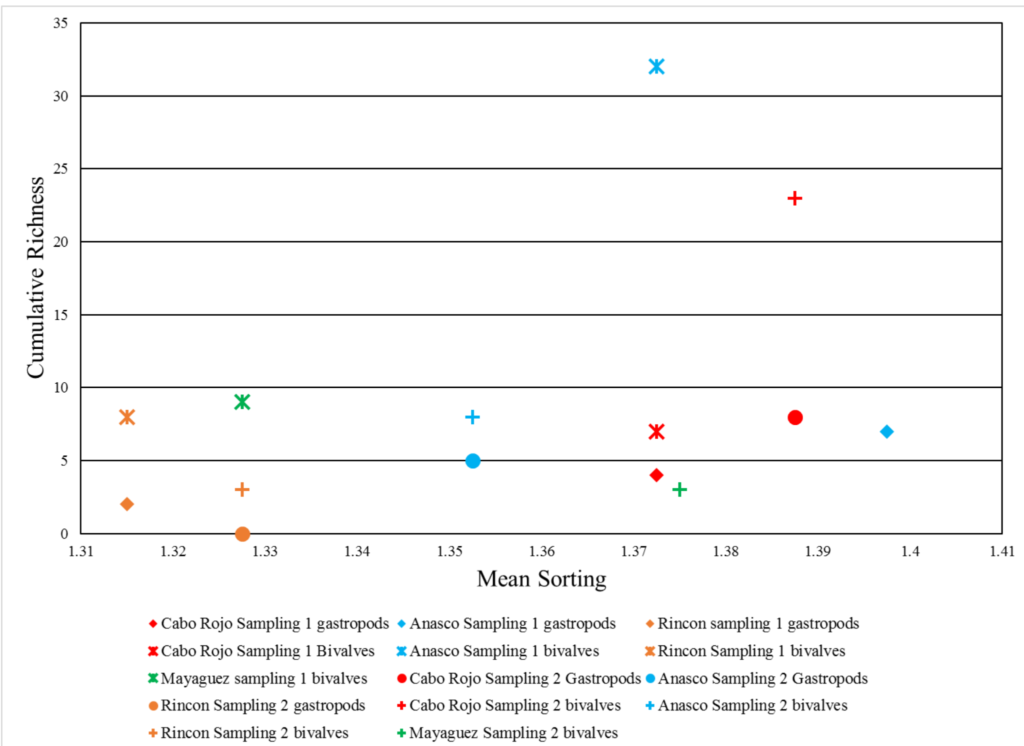

Figure 37. Cumulative richness of gastropods (♦,●) and bivalves (+,*) in the beach face sand zone during both samplings (August/September versus October/November, 2016) versus mean sorting at all locations and both sampling periods.See table 6 for sorting values and sorting categories.

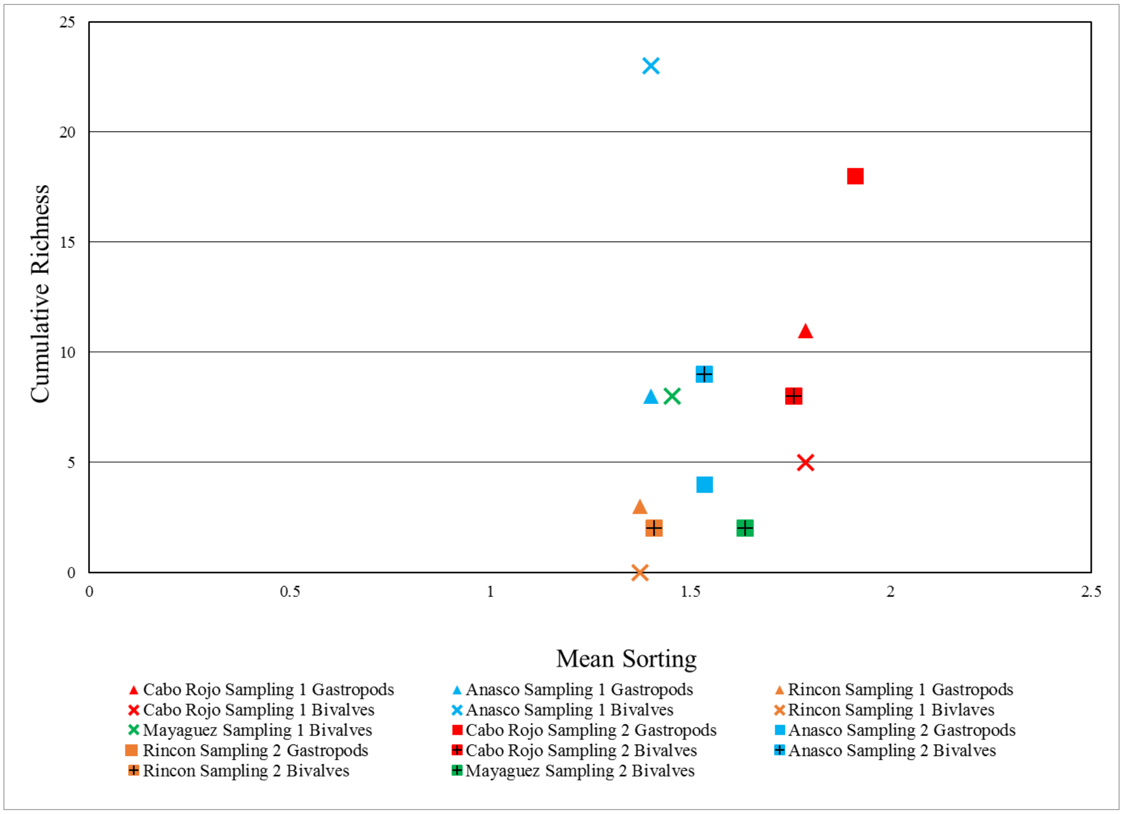

Figure 38. Cumulative richness of gastropods (▲, ■) and bivalves (x, ◘) in the aquatic swash zone during both sampling periods (August/September versus October/November, 2016) at all sampling locations. See table 6 for sorting values and sorting categories.

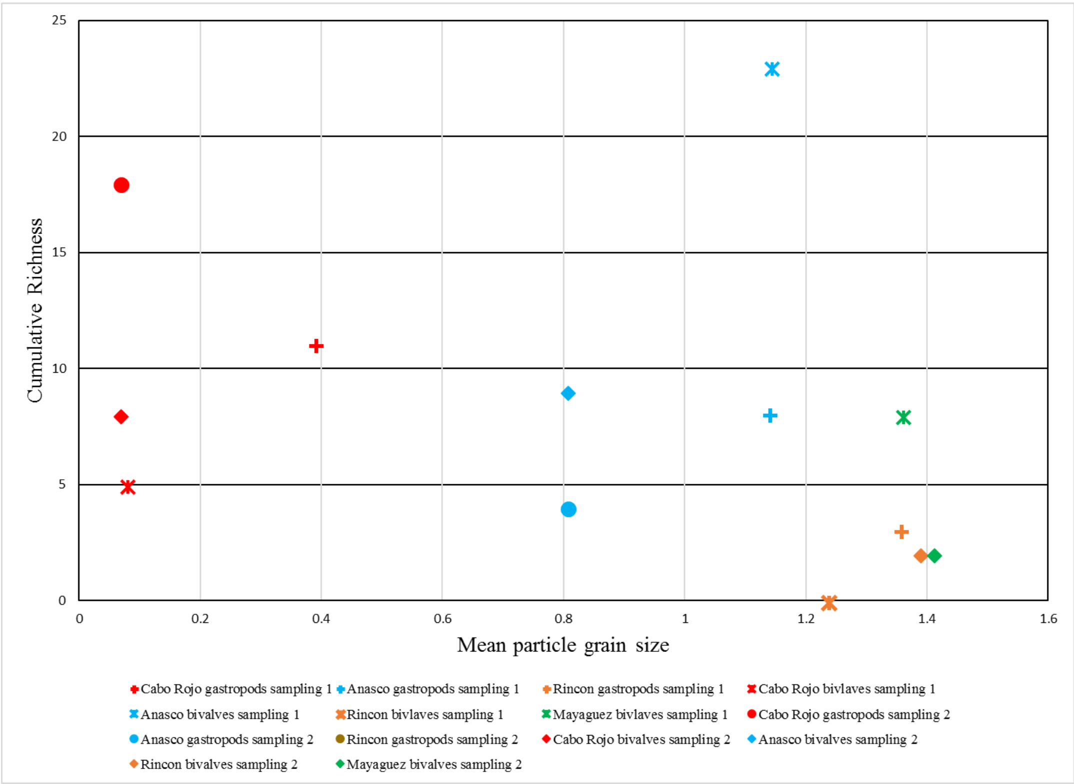

Figure 39. Cumulative richness of gastropods (♦,●) and bivalves (+,*) versus mean particle grain size in the beach face sand zone during both sampling periods (August/September versus October/November, 2016) at all sapling sites. See table 5 for sand class and sand particle grain size (μm).

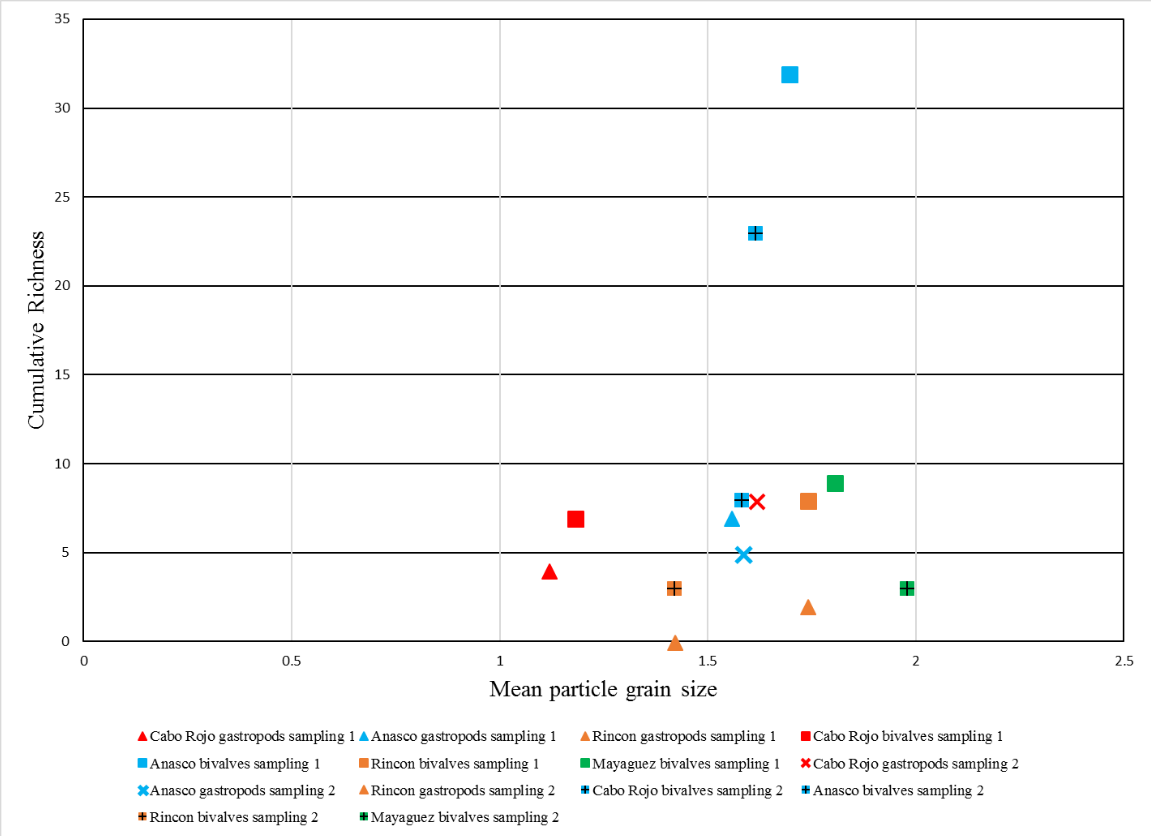

Figure 40. Cumulative richness of gastropods (▲, ■) and bivalves (x, ◘) versus sand particle grain size (µm) in the aquatic swash zone during both sampling periods (August/September versus October/November, 2016) at all sampling locations.

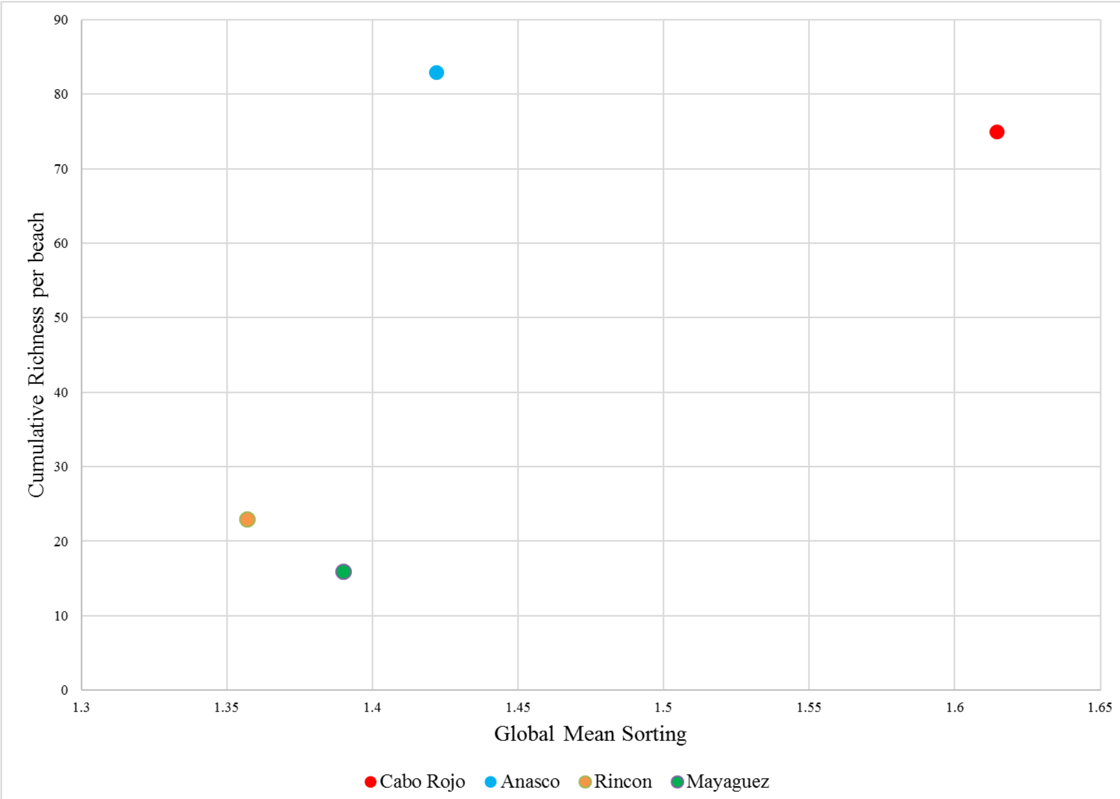

Figure 41. Total cumulative richness of shell-mollusks per location (Cabo Rojo, Añasco, Rincón and Mayagüez) and sampling periods (1 and 2) versus mean sorting per location (both beach face and swash zone included in both sampling periods). Global mean sorting = combining both zones and samplings for each beach.

In Principal Component Analysis (PCA), a biplot uses points to represent the observations on the principal components, and it uses vectors to represent the coefficients of the variables on the principal components (PC1, PC2). The points represent the abundance of the species (bivalves and gastropods) and the vectors represent the abundance of the species found on the selected beaches. Points that are close together correspond to species that are found on two or more of the selected beaches on the plot (Figure 42). The negative values mean that species scores are divided by the species' standard deviations so that abundant of species will be approximately as far away from the origin. The species that looked more distant from the origin in the ordination the bivalves *Donax denticulatus, D. variegata, Americardia sp., Glycymeris* *pectinata, Sphenia sp., Yoldia limatula, Chama macerophylla, Chama sp.* and the gastropod *Psilaxis krebsii.* All other species are close to the origin; thus, the analysis suggests the distribution of the mollusks is related to the sorting, but it did not influence the species biodiversity (Figure 42). The vector points indicate the direction in which squared multiple correlation with the principal components. The percentage of explained variation was 29% for PC1 and 23% for PC2 during sampling 1 (Figure 42-44). PC1 axis corresponds to sand grain size (fine to very coarse sand) and PC2 axis corresponds to sampling zones (beach face sand versus aquatic swash), while the correlation of both axes is related to the species abundance of gastropods and bivalves.

Some of the gastropods and bivalve groups were found to be more abundant in the beach face sand zone than in the aquatic swash zone in sampling period 1. In addition, gastropod species *Sigapatella* and *Olivella minuta* were outliers because their number of individuals was too high in some beaches and were eliminated from the PCA graphs since it could affect the analysis in R Studio (Figure 42-44). Outliers with extreme values can have a strong influence on PCA analyses since they are based on the correlation or covariance matrix and Pison et al. (2003) suggests they should be removed prior to the statistical analysis. In the analysis, it is assumed that samples (beaches locations) that plot nearby have similar grain size class, and that the position of species and sampling locations can be related to environmental variables, such as sorting.

The main association suggested by PCA analysis between species abundance and grain-size, showed a correlation of 52%, (Table 29 and Appendix R, R1) which is low (Figure 42). There is a distribution of the community of species (bivalves and gastropods) regarding the selected beaches at sampling 1; although, some species were found in both Cabo Rojo and

Rincón beaches. The highest number of species was found at Añasco beach. On figures 43 and 44, the arrows that go towards the same direction indicate same sorting with abundance of species, whereas arrows on different directions represent there is no correlation (different sorting).

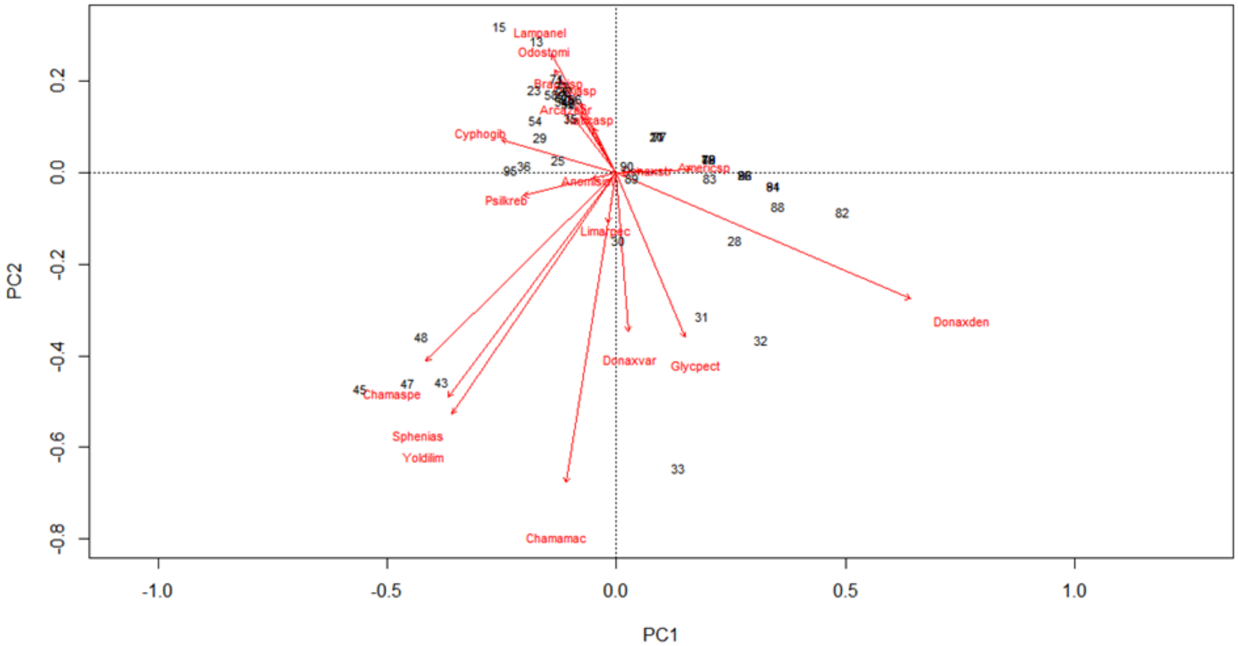

Figure 42. Biplot of the PCA (Principal Component Analysis) carried out on the mollusks' abundances and sorting for the four beach locations from sampling period 1. Vectors represent the number of species, and the mean sorting values. The numbers indicate the quantity of samples collected at the different locations (beaches).

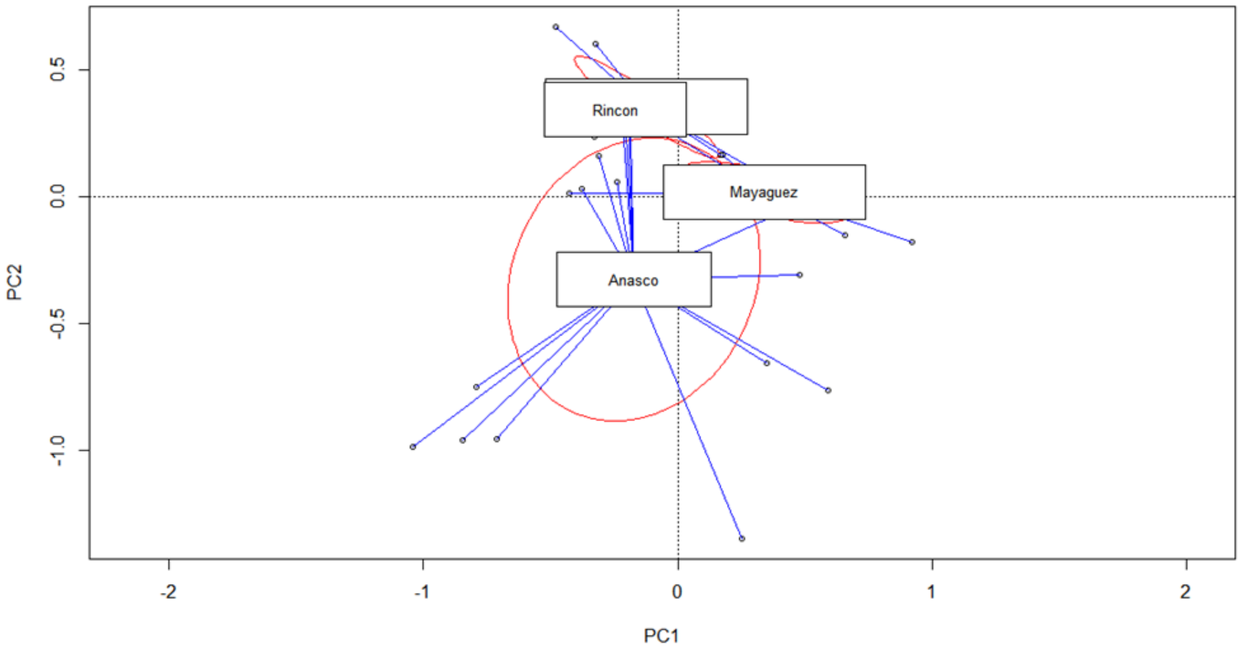

Figure 43. Biplot of the PCA (Principal Component Analysis) carried out on the mollusks' abundances and sorting at the selected locations for sampling period 1. The blue ellipses indicate species/stratum representation. The blue vectors represent species identified at each the beach location.

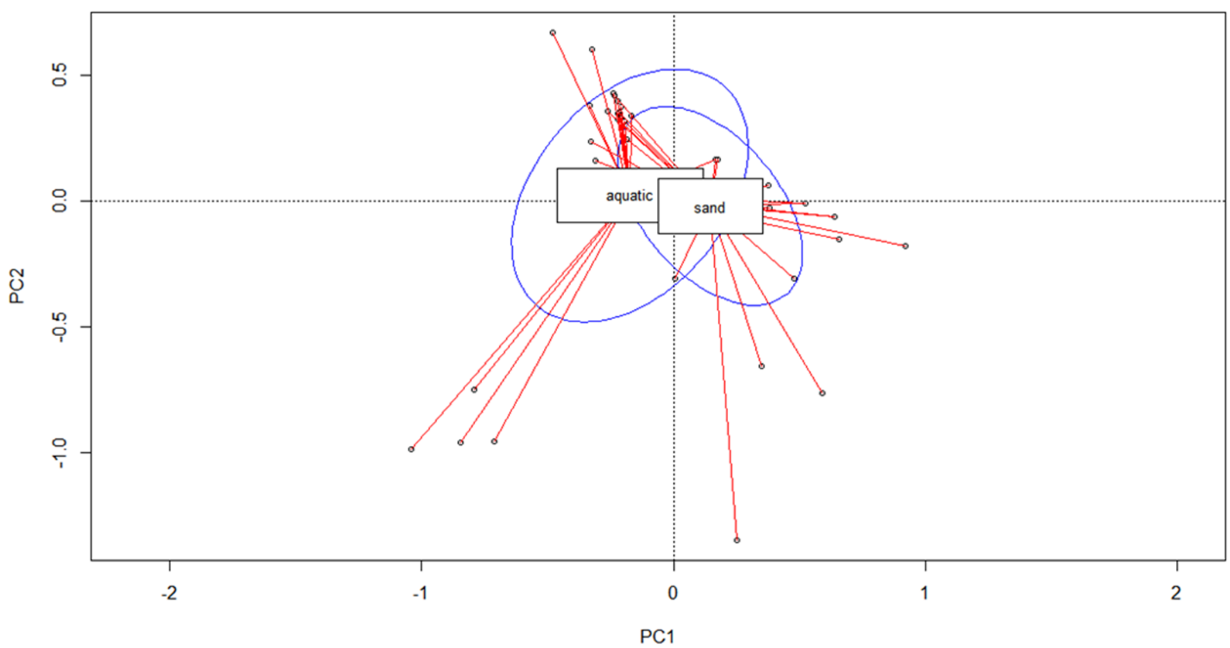

Figure 44. Biplot of the PCA (Principal Component Analysis) carried out on the mollusks' abundances and sorting at the selected locations for sampling period 1. The blue ellipses indicate species/stratum representation. The red vectors represent the species identified at each beach location.

For the sampling period 2, the PCA points also represent the species (bivalves and gastropods) and the vectors represents the abundance of species found at the selected beaches. Points that are close together correspond to species (i.e. *Arca zebra, Trachycardium sp.*) that are found on two or more of the selected beaches on the components displayed in the plot (Figure 45). The species that ordination showed assas distant from the origin were the bivalves *Donax variegata, Anomia simplex., Chama sp.* and the gastropods *Sigapatella sp.* and *Olivella sp.* PC1 explained 59% and PC2 9%, respectively, of the total variation of the species found on the beaches selected during sampling 2 (Figure 45-47). On Figure 45, PC1 axis corresponds to sorting and PC2 axis to zones (beach face sand versus swash aquatic). Again, some of the gastropods and bivalves were found to be more abundant in the beach face sand zone than in the aquatic swash zone at the selected beaches in sampling period 2. The bivalve *Donax denticulatus* and the snail *Lampanella minima* represent species outliers because the individuals present were too high in some beaches and were eliminated from the PCA graphs (Figures 45-47). The positions of the species and sites in the plots are related to beach sand sorting. The main association between species abundance and sorting by PC analysis showed a correlation of 68% (higher than sampling period 1) (Table 29 and Appendix R, R2), which means it was low. There was a distribution of “community of species” (bivalves and gastropods) regarding the selected beaches at sampling 2, and some species were found in both Mayagüez and Rincón beaches but not at the other locations. The highest number of species was found at Cabo Rojo beach (Figure 47).

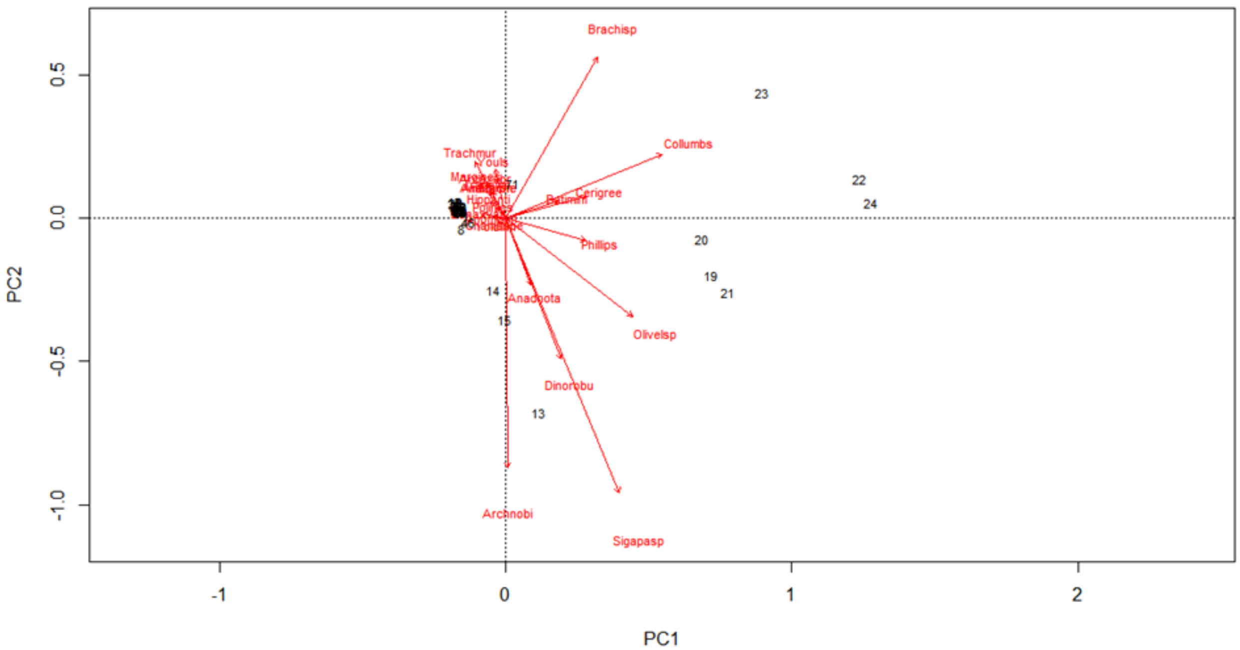

Figure 45. Biplot of the PCA (Principal Component Analysis) carried out on the mollusks' abundances and sorting at the selected beaches from sampling period 2. Vectors represents the species, the sorting and the numbers indicate samples at the selected beaches

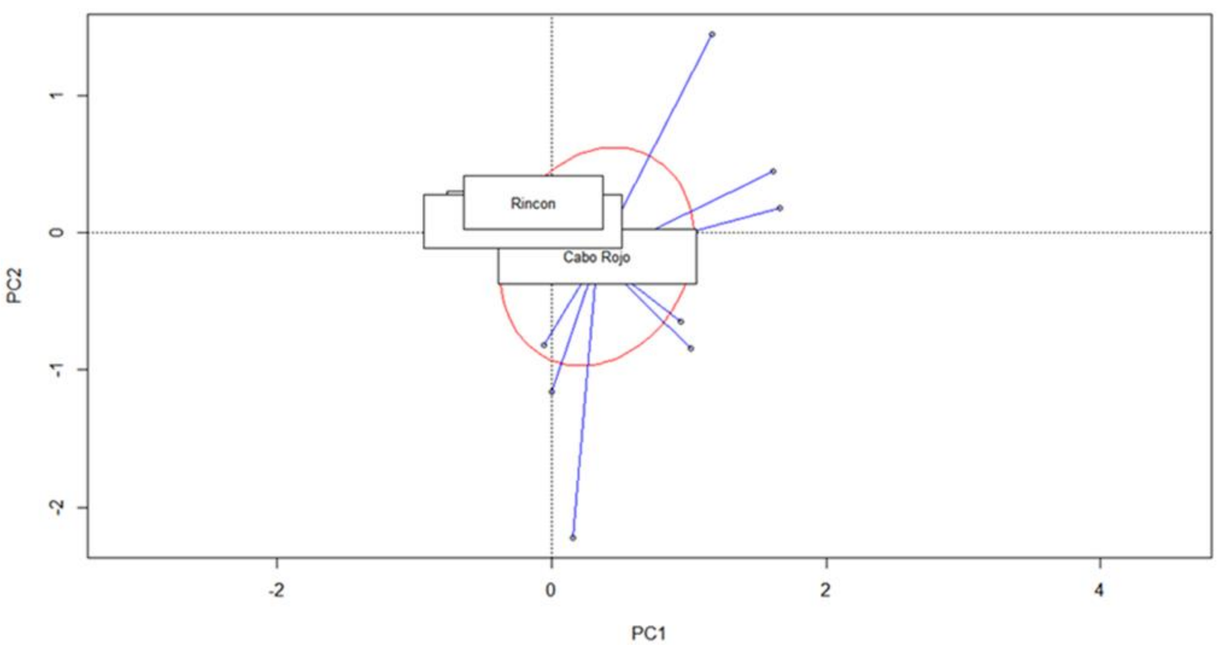

Figure 46. Biplot of the PCA (Principal Component Analysis) carried out on the mollusks' abundances and sorting at the selected beach locations for sampling period 2. The blue ellipses indicate species/stratum representation. The blue vectors represent the species found at each beach location. Mayagüez beach had the lowest number of species.

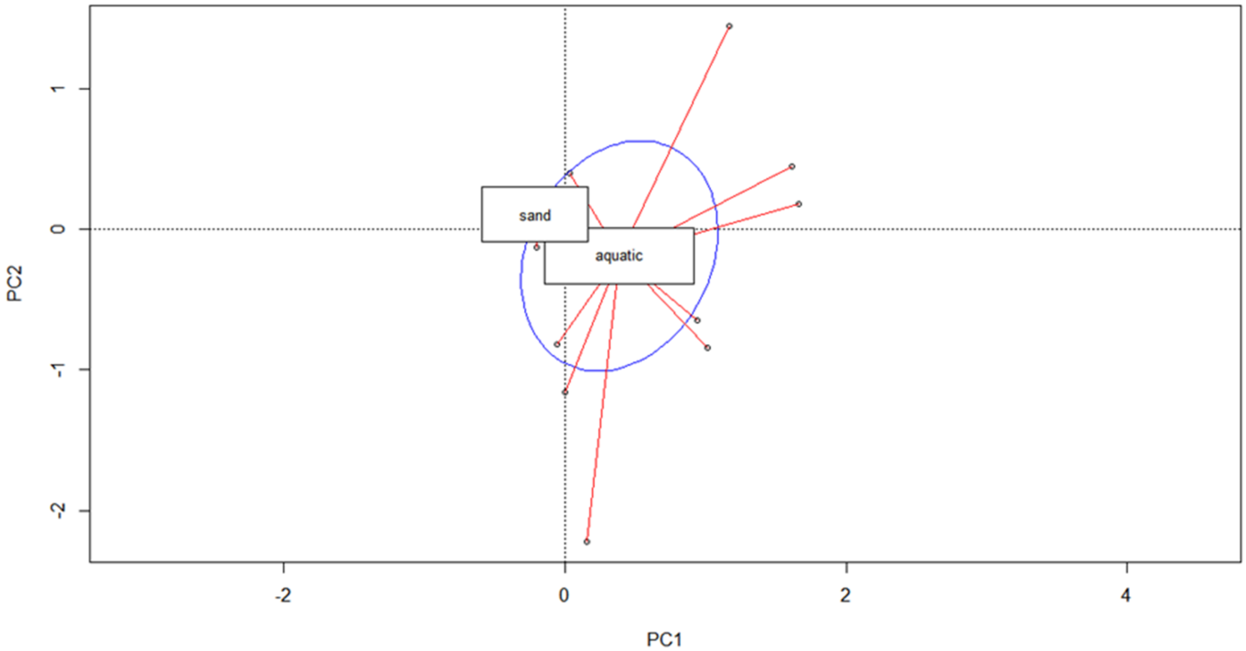

Figure 47. Biplot of the PCA (Principal Component Analysis) carried out on the mollusks' abundances and sorting at the selected beach locations for sampling 2 period. The red vectors represent the species that were found at the beaches.

Table 29. Principal components from sampling period 1 and sampling period 2 at the selected beaches from both zones (beach face sand versus aquatic swash zone).

Samplings	**Eigen values PC1**	**Eigen values PC2**	**PC1 (%)**	**PC2 (%)**	**Total (%) for PC1 & PC2**
Sampling 1	0.5177/1.801	0.4128/1.801	29	23	52
Sampling 2	1.6289/2.772	0.2594/2.772	59	9	68

Dispersion Index

As mentioned before in the methodology based on dispersion index *Echinolittorina ziczac* was found at rocky shores in Rincón and Mayagüez beaches, and it presented uniform dispersion since individuals are evenly distributed over the substrate during this study. Meanwhile, *Cenchitris muricatus* showed a random dispersion since the members of this species were positioned independently (distance far away) from others. It is pointed again that a completely uniform distribution has maximal dispersion, a randomly scattered population has intermediate dispersion, and an aggregated population with clumps of individuals surrounded by empty space has minimal dispersion (Table 30).

Echinolittorina ziczac has an elongated conical spiral measuring 1.3 to 2.5 cm. Its coloration is white with numerous black spiral bands. They get so abundant in the high-water area that in a square meter thousands of individuals can be found (Joglar et al., 2014). This littorinid is widespread in tropical and subtropical regions, occupying a wide range of high intertidal habitats, including mangroves, salt marshes and rocky shores (Stuckey and Johnson, 2003). Reid (1984) found that Australian species of "*Littorina*" were highly mobile, moving from lower levels (*L. articulata*, *L. intermedia*, *L. scabra*) and migrating vertically to avoid submersion. Species that migrate from higher levels (e.g. *L. filosa*, *L. philippina*) moved down to water surface at high tide and were active at night. In our study showed, based on the dispersion indexes, *Cenchitris muricatus* spread evenly through the environment and was highly dispersed, while *Echinolittorina ziczac* species clumped together exhibiting low dispersion. If organisms are attracted to one another, their population shows increased aggregation. Chemical cues or other possible mechanisms of aggregation in *Echinolittorina ziczac* need further studies.

Table 30. Gastropods found in rocky shores using PVC quadrats at the beaches Rincón and Mayagüez.

Date	Beach	Scientific Name	Average number per quadrat	Variance	Index of Dispersion
09/02/2016	Mayagüez	*Cenchitris muricatus*	15.33	123.55	8.06
09/02/2016	Mayagüez	*Echinolittorina ziczac*	56.33	3.55	0.06
11/18/2016	Mayagüez	*Echinolittorina ziczac*	22.66	222.89	9.83
11/18/2016	Mayagüez	*Cenchitris muricatus*	0.5	0.25	0.5
05/10/2017	Mayagüez	*Cenchitris muricatus*	46.66	1840.89	39.44
05/10/2017	Mayagüez	*Echinolittorina ziczac*	40.33	1397.56	34.65
09/16/2016	Rincón	*Echinolittorina ziczac*	35.66	234.88	6.58
11/04/2016	Rincón	*Echinolittorina ziczac*	24.33	259.22	10.65
05/12/2017	Rincón	*Echinolittorina ziczac*	63.67	3097.56	48.65

T-test

T-tests were used to compare between pairs of groups of bivalves and gastropods, assuming that compared samples are independent. As seen on Appendix N (Tables N1 -N6), T-tests were used to prove whether or not the two compared groups had significance difference between them in the number of bivalves found in the selected beaches within variables beach, time (August/September versus October/November), transects (T1, T2, T3, T4) and zones (sand versus aquatic). As seen on Appendix N (Tables N7- N12), T-tests were also used to prove whether or not two groups had significance difference in the number of gastropods found within variables beach, time (August/September versus October/November), transects (T1, T2, T3, T4) and zones (sand versus aquatic). All tables of the number of bivalves and gastropods that were found at the selected beaches during both samplings are in Appendix N (N1-N12).

Shapiro Wilks

Shapiro Wilks analysis was used to test for the normal distribution in the samples. Since p was lower than 0.05, the data did not show a normal distribution. Appendix O (Table O1) shows where there were significance differences in the abundance of bivalves for the variables time, transect, zone and beach. In addition, Appendix O (Table O2) shows where there were significance differences in the abundance of gastropods for variables time, transect, zone and beach.

Discussion

Comparison of grain-size attributes between the selected beaches

Mean grain size and sorting are fundamental parameters to describe sediment properties and information on the dynamics of the beaches (Carranza-Edwards, 2001). Comparisons of grain size and sorting (granulometry) among different locations (the selected beaches) indicated slight differences in grain size and sorting (all transects) beach face sand versus aquatic swash areas (two different zones studied at each location).

The coastal zone of the west coast of Puerto Rico is endowed with varied lanscapes such as sandy beaches, rocky beaches, lagoons, rivers (i.e. Añasco river), water streams and other ecosystems. The coast is constantly submitted to physical changes in the geological past and present. Añasco and Mayagüez beaches are influenced by have several major rivers draining into their embayments. These rivers bring considerable sediments, loads, from both natural and anthropogenic origin in nature; thus, affecting more the coast shore processes. This is a fundamental difference between these locations and the Cabo Rojo and Rincón locations that do not have riverine inputs close to them.

Textural analysis carried out at the four different locations for the revealed that beaches associated with rivers were dominated by fine to very coarse sand. The sorting values for most of the samples at selected beaches fall into the poorly sorted and very poorly sorted. The grain size values as well as the mean sorting were very similar for the beach face sand zone in all locations (Appendix B- I). These results were similar to Carranza-Edwards (2001), the only difference is that his work was more focused in the difference in the sand composition in the backshore, foreshore and inshore levels of the beach. Grain size analysis found that sands had larger sizes in the inshore beach. This could be due to the breaking of the waves in this zone. Carranza-Edwards (op.cit.) demonstrated that the sands with greater terrigenous components averaged finer sizes than the sands of carbonated beaches, in different locations. Our data indicates dominance of medium coarse and very coarse sand in both zones the beach face and the aquatci swash zone.

Biodiversity of shell-mollusks at studied locations

The shell-mollusks of the coastal beaches are very important components of the tidal channel (high and low tides). There are several well-defined habitat types along the shore, with their own characteristic shape. The tides influence the character and distribution of the mollusks that inhabit the seashore (Penagos, 2013).

According to Bouchet et al. (2002), mollusks species richness has been often underestimated in ecological studies mostly because of an inadequate coverage of the spatial heterogeneity and sampling effort. The assessment of sampling effort is particularly important in the case of molluscan assemblages. Most of all papers dealing with methodology show the collection of the specimens by digging out in transects in a known area or using quadrats of known size to assess the biodiversity. González Liboy (1971), in his study at Mayagüez beach, pointed out that beaches are constantly changing in shape and appearance and, because of this, the establishment of beach animal zones ceases to be limited only by tidal amplitude, nature substrate, the waves and the wind which modifies forces making difficult to define exact limits on the littoral zone on the sandy beach.

Esqueda-González et al. (2014) showed that most diverse families of beach-dwelling mollusks were Mytilidae, Veneridae, and Arcidae. In their study, ten families (35%) included only one species. The number of species increased from the upper (44) and lower intertidal (53) to the shallow subtidal (76). In addition, the numbers of unique species per zone were 7 for the upper, 4 for the lower, and 18 for the subtidal. The species richness was similar among samples from the shallow subtidal zone of all beaches (28–36 species), except for Venados Island (55 species), which had the highest number of species restricted to this locality (7). In our study, the most diverse bivalve families were Arcidae (11 species) and Cardiidae (13 species), and in the gastropods Fissurellidae (8 species) and Cerithiidae (5 species), as seen on Table 8.

Monolisha and Patterson (2015), in their study about the biodiversity of marine mollusks in Tamil Nadut, Eastern India, observed 20 species of bivalves and 41 species of gastropods collected from 8 sampling transects, twice the sampling effort per beach conducted in our study. We observed 83 bivalve species and 50 gastropods species from 4 sampling transects during both samplings at the selected beaches, stressing out the relatively high species richness in the surveyed beaches.

Aldea and Rosenfeld (2011) were interested in the biota of Buque Quemado beach, Chile. During low tide, they carried out a through visual inspection in a transect perpendicular to the coastline from the upper intertidal zone to the lower intertidal, conducting an *in-situ* collection of living organisms by manual extraction and spatulas. Their results rendered a total of 218 mollusks individuals, distributed into 12 species: 9 Gastropoda, 1 Bivalvia, and 2 Poplyplacophora. Despite the great extent of that intertidal zone, it was dominated by large soft substrate extensions, presenting isolated patches of rock or small boulders. In our study, all samples were also collected during low tide, but samples showed samples higher diversity of bivalve species than gastropods in beaches such as Cabo Rojo and Añasco especially on sampling 1 (August/September).

Kurhe et al. (2014) studied the vertical distribution, species diversity, ecological preferences and abundance of gastropod mollusks in the intertidal regions in fourteen localities located along the coast of Ratnagiri Maharashtra, India. The gastropods were also collected during the low tide. Eight of their localities were very similar in habitat type (open coast, stones and gravels and coarse sand along with shoreline), but six other localities were totally different in habitat because of fishery activities. A total of 127 gastropod species from 20 families were identified in the fourteen localities. Species common to all localities were *Cerithium morus, Cerithium sp., Littorina scabra, L. (Littorinopsis) angulifera, Tectarius thiarella, Tectarius sp., Cellana radiata* and *Planaxis similis*. The species *Littorina scabra, Tectarius coronatus, Nerita ornatus, Planaxis niger, P. acutus* and *Cerithium sp*. were found in 13 localities; 4 species (*Nerita melanotragus, Thais clavingera Planaxis sulcatus* and *Cerithium rubus*) were found in 12 localities; 4 species (*Gyrenium notator, Tectarius muricatus, Nerita albicilla*, and *Cerithium sp*.) were collected in 11 localities and many others were found in 10 or fewer localities. In our research we found 50 gastropod species from 25 families from only four localities (see Table 8).

In the study by Kurhe et al. (op.cit.), the similarities between the first eight mentioned localities were above 50%. In contrast, the six localities impacted by intense human activities showed lower similarities and lower species densities. In our research, based on the Jaccard Similarity Index values, there were low similarities between the four beaches (4-17%). This may be caused by some of these beaches being influenced by rivers, while some are not. Proximity to river mouths could be considered as a factor affecting both the organic material present in the different beaches and sand minerology.

Monolisha and Patterson (2014) aimed their study for the biodiversity of shell-mollusks in the shoreline of the Anadhra Pradesh coast (India) by using quantative analysis and identification from eight locations. In their results, the Shanonn- Wiener index for gastropods range from 1.36 to 1.47. For bivalves its range was 1.11 to 1.21, and for the cephalopods it ranged from 1.06 to 1.43. In our research, the Shannon-Wiener index varied from as low as 0.63 for bivalves in El Maní beach during sampling 2 to as high as 3.65 for bivalves in El Combate during sampling 2. In Monoloisha and Patternson study, samples of mollusks were collected from eight locations covering four coastal districts (Guntur, Prakasam, Krishna and Nellore). In contrast, our study was based on only four locations.

Torreblanca-Ramírez et al. (2014) studied seven sites in the coast of Guerrero, Mexico, to determine the biodiversity of gastropods. All sites differed in the wave exposure of the substrate, rock type and others. All samples were collected during low tides and using quadrats. They collected 11,263 specimens and identified 108 species, of which four species were new records for Mexico. In our study, none of the species identified to species-level represents a new record for Puerto Rico. However, 37% species were identified to genus level only; these might include novel species for the Island.

Ocaña et al. (2015) described spatial-temporal variations in abundance, size structure and length-weight relationship for a population of the bivalve *Donax denticulatus* at Levisa Beach, on the Southeastern coast of Cuba. Monthly samplings were performed in four stations located along the beach. Two-way ANOVA was used to test for spatial and temporal differences in the clam density. Some 4,570 clams *Donax denticulatus* were collected and measured and results showed no significant differences in abundance among the months of study but indicateded higher abundance in the middle intertidal zone. In our project, the cumulative frequency of *Donax denticulatus* was relatively high in all selected beaches during both sampling periods.

Poulami et al. (2014) studied the distribution, species richness and relative abundances at family- and species-levels over different seasons at five sites in the northeastern coast of India. They identified 31 species of gastropods and 32 species of bivalves. They also used the Shannon-Wiener index to determine the number of mollusk species for a season. The fauna of molluscs was shown to vary seasonally. The lowest diversity was recorded in July because of the monsoon season, when the salinity and temperature are low. The population density increased in the months September to December during post-monsoon season. We were able to conduct only two samplings per locality; thus, temporal changes in the mollusk composition in our beaches needs further assess seasonality.

Esqueda-González et al. (2014) showed the composition and distribution of bivalve mollusks from the sandy and rocky intertidal zones of Bahía de Mazatlán, México. At the end, they had a total of 21,694 bivalves of 28 families, 55 genera, and 89 species. Their work was similar to that of Poulami's paper, the only difference was that Esqueda-González used species accumulation curves graphs to show the bivalve diversity in sandy and rocky shores. The species accumulation curves revealed that species representativeness ranged between 64 and 80% in the four sampling sites. In Esqueda-González et al. (2014) fieldwork was based on six sampling sites exposed to wave action conditions that were established along Bahía de Mazatlán: four rocky beaches and two sandy beaches. Three environments were considered in each site: upper intertidal, lower intertidal, and shallow subtidal (3–10 m depth) adjacent to each beach. Also, different sampling techniques (transect and quadrats) were applied during four expeditions (December 2008, through March, June, and August 2009). In our study, we used four transects on each of the selected beaches (4 locations), with sampling techniques (PVC plastic tubes 1m depths and 2 x 2 feet PVC quadrat) with two zones (beach face sand and aquatic swash) in August through November 2016.

As previously stated, in our study we recorded a total of 83 species of bivalves, from 30 families and 53 genera, and a total of 50 species of gastropods from 25 families and 34 genera from the four selected beaches. Based on the Shannon-Wiener Index, our study showed that diversity of the molluscs varied among the beaches, as also was found by Monolisha and Patterson (2014).

Correlation between grain sizes and shell-mollusks

Few studies have assessed influence of grain size in bivalves and gastropods populations. It remains an unknown subject, especially in the Caribbean. Natural processes in ecosystems, especially in marine habitats, show significant variations in species richness, which can be influences by natural or anthropogenic factors. Flores-Rodríguez et al. (2012) considered how environmental factors relate to the species richness in rocky intertidal mollusks, track the geographical distribution of the species, and determine changes in species richness related to rainfall. They studied sites in the State of Guerrero, Mexico, and found that gastropods had higher dominance through their geographical sites. In addition, they found that during the rainfall season the number of species of mollusks did not change in the rocky intertidal zones. Also, high species richness was related to low variations in water temperature and presence of complex substrates. These conditions create habitats in which mollusks and other organisms can be protected and become more established. It was concluded that these habitats in the State of

Guerrero showed a distinctive fauna and that the number of species in study sites as well as spatial representation was affected by the variety of substrates and wave intensity.

Nel et al. (2001) explored the effect of grain size (sediment grain sizes of a well-sorted and moderately sorted nature) on longshore distribution of sandy beaches at the Eastern Cape, South Africa, with emphasis on the bivalves species *Donax serra* and *D. sordidus.* They chose these species because they are macrobenthic inhabitants of intermediate and dissipative beaches and most species evolved to be tidal migrants, burrowing rapidly into the beach sediments during tidal waves. They determined that there was a significant and positive relationship between shell length and burial time with sand grain sizes. Specifically, *Donax serra'*s burial time was related to sediment sizes. *Donax sordidus* burrowing cycles also varied in association with different grain sizes. They observed that slowest burial times were measured when there was a mixture of coarse and fine sediments (poorly sorted sediments). The clams appeared physically unaffected by the changes in size and sorting of these sediments. They concluded that small invertebrates generally had faster burial times than large invertebrates in all sand grain sizes and, thus, they are expected to be successfully adapted in most beaches with wide range of grain sizes and sorting. In our study bivalve's burial time was not considered. Despite this, and the changes in size and sorting of the selected beaches there were no variations between the bivalves and sand grain size and sorting.

Research by La Valle et al. (2001) aimed to determine the relationship between *Donax trunculus'*s density distribution and sediment grain size. They evaluated the possibility of using this species as a biological indicator of grain-size variation. They performed collections in six samplings sites in the Central Tyrrhenian Sea, Italy, at different sand depths (0, 0.5 and 1 m). They chose *Donax trunculus* because the shape of its shell allows easy penetration into the sediment. PCA analyses indicated the sediment grain size was a factor controlling the distribution of bivalve's populations in well-sorted to very-sorted grain size classes. They concluded that this bivalve can be used as a biological indicator to detect sand grain size variations and as a useful tool for researchers to assess beach erosion. In our study, *Donax denticulatus* distribution was observed in all selected beaches and was not affected by grain size variations. Moreover, it is known to be a key mollusk for the ecology of sandy beaches. Additionally, serving as a bioindicator of contamination, especially at Mayagüez and Añasco beaches (González- Liboy, 1971; Sastre, 1984, 1985).

In the coasts of Oregon, Alexander et al. (1993) investigated how burrowing rate of bivalve species varied according to the textural properties of the sediments. Most of these burrowing rates were measured in sediments with 1.5 to 3.0 phi. All bivalve species were categorized into specialists, generalists, or sensitive depending on their life habits and effects caused by sediment grain size. They concluded that most species were able to burrow in medium to fine grain size sands. Specialist species burrow most rapidly in coarse grain size or finer sands. Substrate generalists were slow burrowers but penetrated very coarse sand to mud. Sensitive species included both rapid and slow burrowers and had specificity for sediment textural distribution (coarse to fine sands). In our study, the mollusks were naturally exposed to sediments with -1 to 4.0 phi. The correlation between the abundance of burrowing bivalves and substrate distribution requires further research and testing. However, the classification of specialist and generalists was not attempted because the range of grain sizes was small.

Hunt (2004) determined the relationship between sediment transport and bivalve dispersal using juveniles of the clams *Mercenaria mercenaria* and *Mya arenaria*. They also examined the effect of grain size and clam size on rates of erosion of coastal rocks. Juvenile clams were used in their study because these often live close to the sediment surface, where they are eroded by waves and currents. They used experiments in which the two clam species were examined at two shear velocities and two sediment grain sizes. Erosion of *Mercenaria* was greater than for *Mya*, indicating importance of burrowing behavior. Clam erosion increased with shear velocity and decreased with clam size. Burial time was not used in our study and *Mercenaria* and *Mya* species were not found at the selected locations.

McLean (1967) showed that some gastropod species are more efficient erosional agents than others and substrate characteristics and depth of algal penetration influence the amount of erosion. Six gastropods species were used in his study (*Cittarium pica, Littorina meleagris, Echinolittorina ziczac, Nodolittorina tuberculata, Nerita tessellata* and *N. versicolor*) since these contribute to erosion of rocks by scraping algal with their radular teeth. All samples were obtained with range 0.5 to 1.0 mm, within the rock with coarse grain size. Also, variations in substrate characteristics, like grain size, mineralogy composition, and others, are likely to have an important influence of erosion by gastropods, which means that there is a relationship between erosion by gastropods and rock substrate grain size. *Cittarium pica* was the most efficient erosion agent based on the variation in hardness of the scrapped materials. The amount of rock erosion by these herbivorous gastropods depended on numerous factors including animal size, rock hardness and depth of algal penetration.

In our study, sediment grain size and sorting did not alter or affect mollusk biodiversity. Factors that could have affected the sorting are tides and the exact location where samples were taken from which affects how much water is in the samples. Finally, wind patterns and local hydrodynamics (i.e. wave breaking) affect grain size and distributions (Carranza-Edwards, 2001). The closer to the waves the bigger the grain; further away from the waves breaks the grain size usually decreases, as smaller sediments are favored by water and wind transport and changes in grain distribution observed in the direction of transport are related to vertical changes within the sediment transport profiles (Arens et al., 2002). The origin of the samples also affects the size, shape and texture of the grain. In the analyzed beaches, medium and fine sands prevailed, with a higher dispersion of data for coarse and very coarse sand classes (Carranza-Edwards, 2001). Studies focused on the monitoring of gastropod species (native and nonnative), and the knowledge on species diversity, distribution patterns, and substrate preferences are a must for the conservation of littoral mollusks in the Caribbean, and elsewhere.

Conclusion

- The dominant grain size sediments in four studied beaches were medium to very coarse sand, with some fine sands present. The sorting values for the four studied beaches along the west coast are mostly poorly sorted with few poorly sorted samples.

- According to the size frequency distributions of foreshore materials, there were marked differences in the range of mean size grades occurring on the four selected beaches. However, mean sorting, grain particle size and abundance of shell-mollusks were not correlated with each other.

- Patterns of abundance and species richness of both gastropod and bivalves showed significant differences among transects and same beaches. The null hypothesis, stating that patterns of abundance and species richness of both gastropods and bivalves would not show significant differences among transects set in a same beach, is rejected for some of the beaches (Cabo Rojo, Añasco and Rincón).

- Differences among the samplings, zones (sand versus aquatic), and transects suggest that each selected beach has a distinctive fauna.

- Total number of species of gastropods and bivalves found in the four beaches were 50 and 83, respectively. Dominant species, based on cumulative abundances, were: *Donax denticulatus*, *Chama macerophylla*, and *Yoldia limatula* (bivalves), and *Sigapatella sp.* (gastropod).

- Number of species per beach and most abundant species based on the number of individuals is *Sigapatella sp*, *Olivella minuta*, *Lampanella minima* (gastropods) and bivalves *Anadara chemnitzii* and *Donax denticulatus* Cabo Rojo (sampling periods 1 and

2). In Anasco (sampling periods 1 and 2) *Donax denticulatus* and *Trachycardium sp.* (bivalves) and gastropods *Polinicies sp.* and *Olivella sp*. In Mayagüez (sampling periods 1 and 2) *Donax denticualtus*. Finally, Rincón (sampling periods 1 and 2) was *Yoldia sp*., *Donax striatus* (bivalves) and gastropods *Olivia sp.* and *Psilaxis krebsii*.

- Cabo Rojo, Añasco and Rincón presented sand grain size dominance in medium sand to very coarse sand. Meanwhile, Mayagüez had dominance of medium sand.

- Shannon Wiener Index showed that molluscan diversity varied significantly among the beaches in the two sampling periods. Jaccard Similarity Index values, there were low similarities between the communities of the four beaches (4-17%). Dispersion Index suggested that the species *Echinolittorina ziczac* presented uniform dispersion while *Cenchitris muricatus* showed a random dispersion.

- According to the principal component analysis, sorting and biodiversity of mollusk were correlated in 52% o for sampling period 1 and 68% for sampling period 2, which are relatively low and moderate values, respectively.

Recommendations

Although this study involved a great effort, and since it probably was the first time established in the Caribbean, it ultimately showed that the relationship between grain size and sorting and the marine mollusk biodiversity were not associated with each other in local beaches on the west coast of Puerto Rico. It is advisable to increase the number of samplings or visits to these localities. Based on our results, sediment sorting and grain size did not correlate with biodiversity of shell mollusks. Future studies should increase sample size per visit and included more than two samplings over a year. Since Puerto Rico experienced two hurricanes category 5 (Irma and María in 2018), we could establish differences in the grain size, sorting and abundance of mollusks before and after the hurricanes. There are other important sedimentary aspects like sand composition (carbonate verus terrigenous material) and mineralogy that may influence mollusks populations. For future studies, we recommend the analysis of wave distributions, turbulence, rising of sea level, mineralogy and sand composition in addition to sand texture.

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Appendices

Appendix A

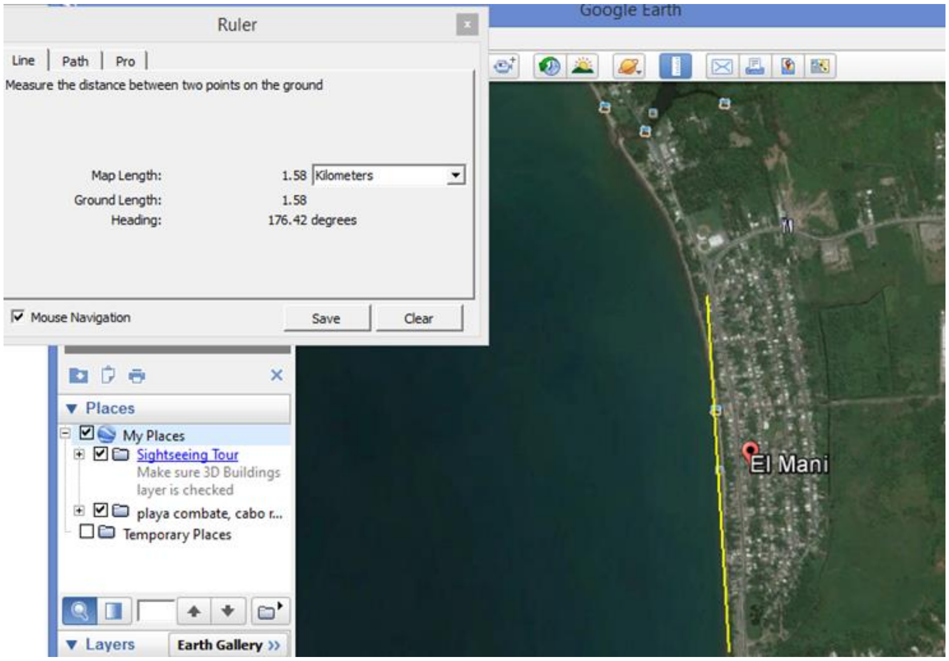

Figure A1. Profile of El Maní beach, Mayagüez.

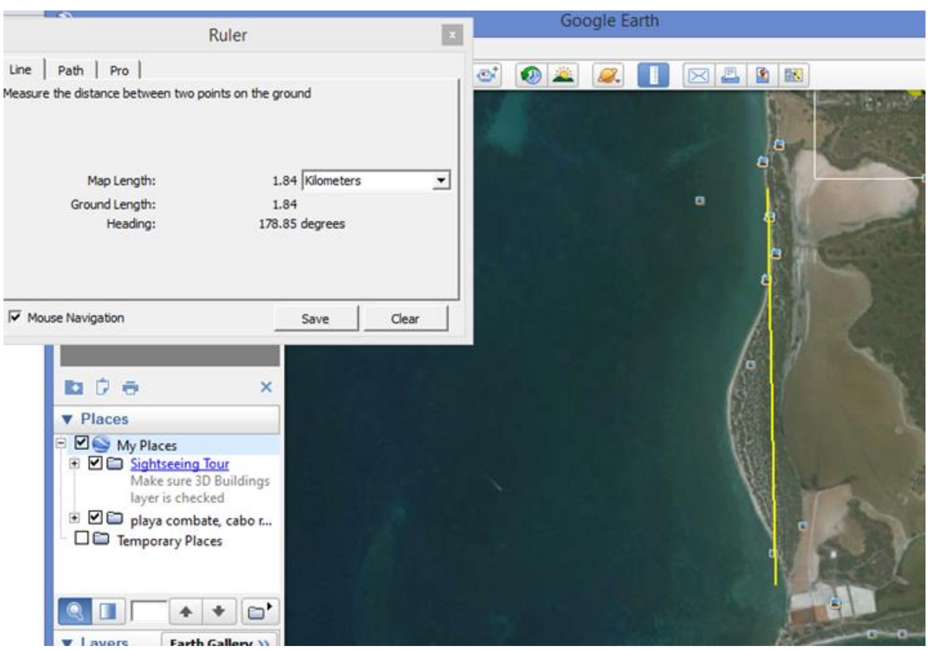

Figure A2. Profile of El Combate beach, Cabo Rojo.

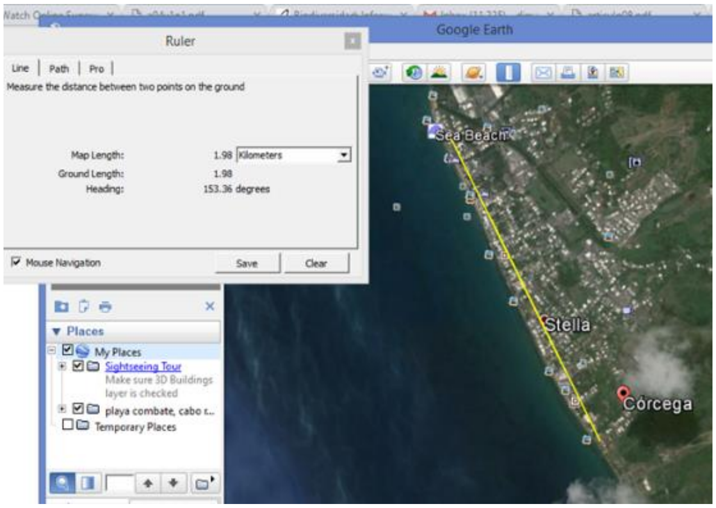

Figure A3. Profile of Córcega beach, Rincón.

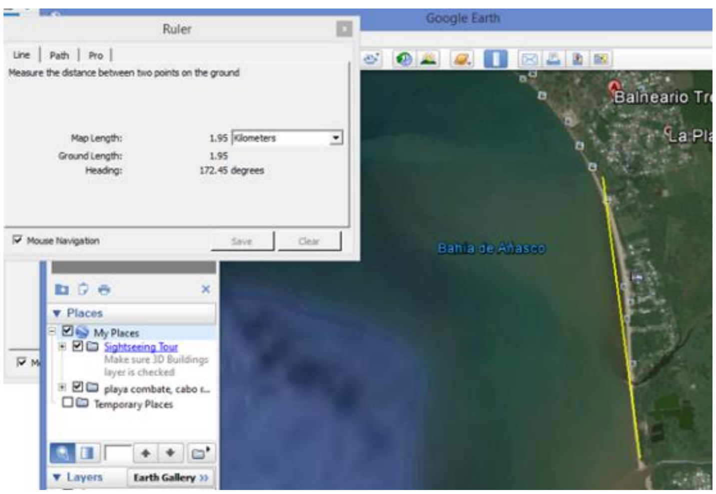

Figure A4. Profile of Balneario Tres Hermanos beach, Añasco.

Table A5. Timetable

Beach	**First visit**	**Second visit**	**Analysis of sand composition for first visit**	**Analysis of sand composition for second visit**	**Statistical analysis and writing**	**Thesis Defense**
El Mani, Mayagüez	**August 26, 2016**	**October 7, 2016**	**Mid-September**	**October - November**	**Several months**	**May- June 2017**
El Combate, Cabo Rojo	**August 26, 2016**	**October 21, 2016**	**Mid-September**	**October - November**	**Several months**	
Córcega, Rincón	**August 29, 2016**	**November 8,2016**	**Mid-September**	**October - November**	**Several months**	
Balneario Tres Hermanos, Añasco	**August 30, 2016**	**October 11, 2016**	**Mid-September**	**October - November**	**Several months**	

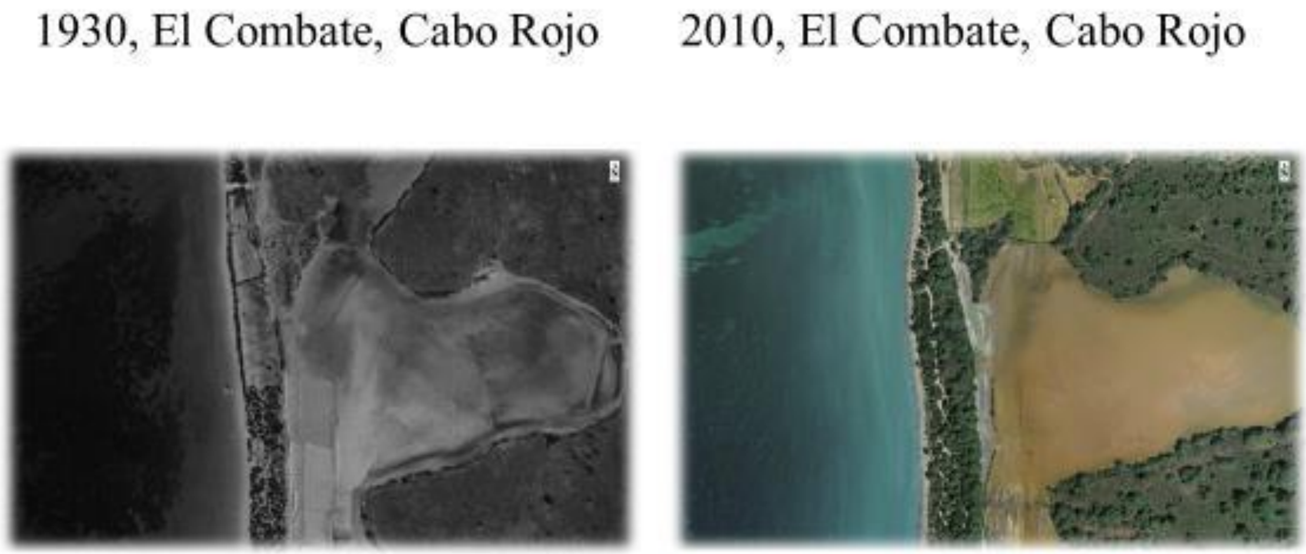

Figure A6. Aerial Photography Images from 1930 and 1950 of El Combate beach, Cabo Rojo

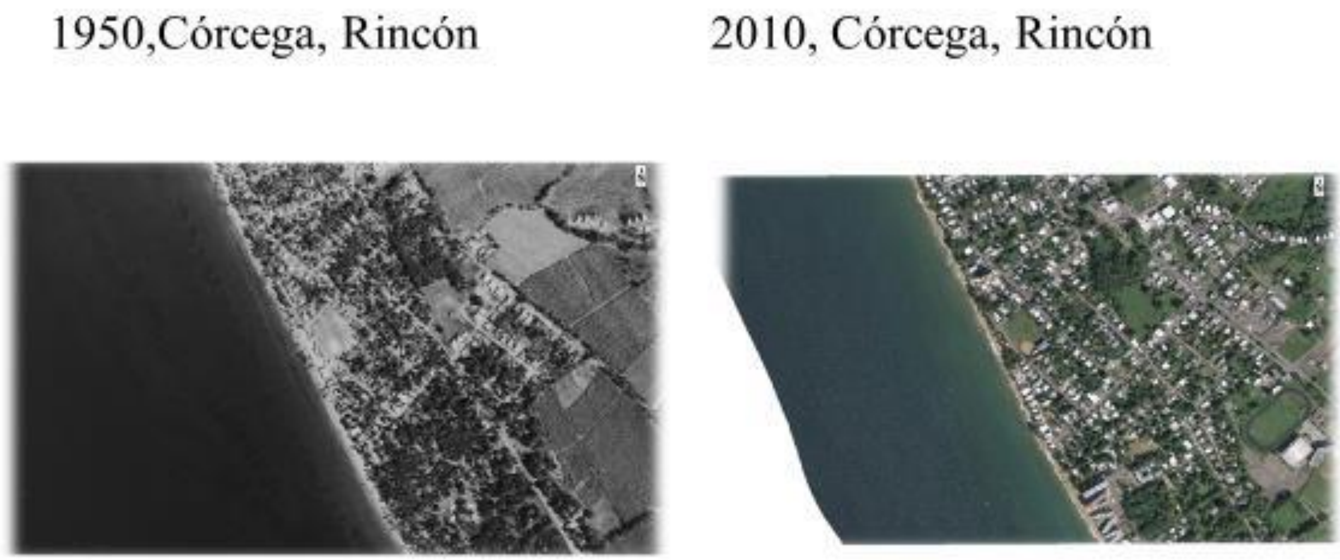

Figure A7. Aerial Photography Images from 1930 and 1950 of Córcega beach, Rincón

Figure A8. Aerial Photography Images from 1930 and 1950 of El Maní beach, Mayagüez

Figure A9. Shoreline changes from 1930 (yellow line) to 2010 (blue polygon), based on aerial images, at El Combate beach, Cabo Rojo.

Figure A10. Shoreline changes from 1950 (yellow line) to 2010 (blue line), based on aerial images, at Córcega, Rincón.

Figure A11. Shoreline changes from 1950 (yellow line) to 2010 (blue line), based on aerial images, at El Maní, Mayagüez.

Appendix B

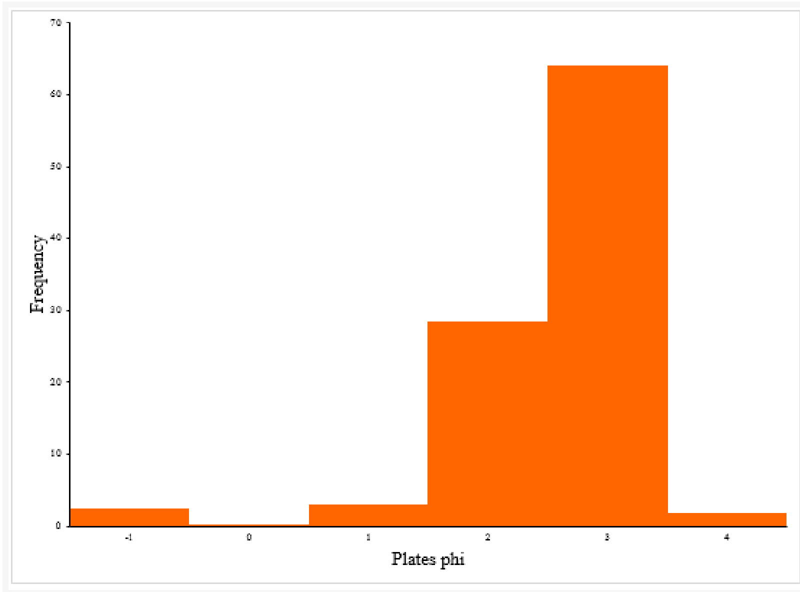

Figure B1. Frequency histogram of the particle grain size distribution for sample 1 from transect 1 in Añasco beach during sampling 1 (August/September 2016).

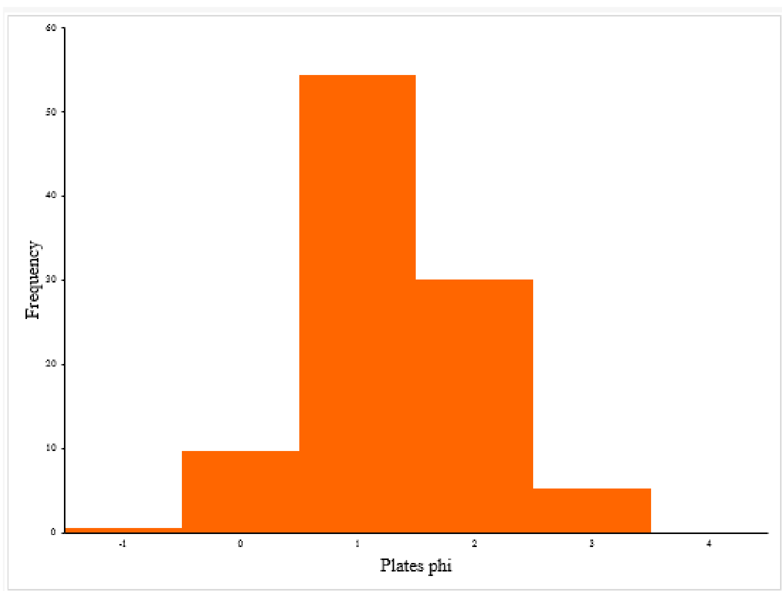

Figure B2. Frequency histogram of the particle grain size distribution for sample 4 from transect 1 in Añasco beach during sampling 1 (August/September 2016).

Table B3. Granulometry calculation for Transect 1, samples 1 and 4 at Añasco beach in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 1			
Sample 1	-1	2.5	2.47
	0	0.2	0.19
	1	3.1	3.07
	2	28.6	28.34
	3	64.6	64.02
	4	1.9	1.88
	Total	100.9	
Sample 4	-1	0.5	0.51
	0	9.5	9.72
	1	53.2	54.45
	2	29.4	30.09
	3	5.1	5.22
	4	0	0
	Total	97.7	

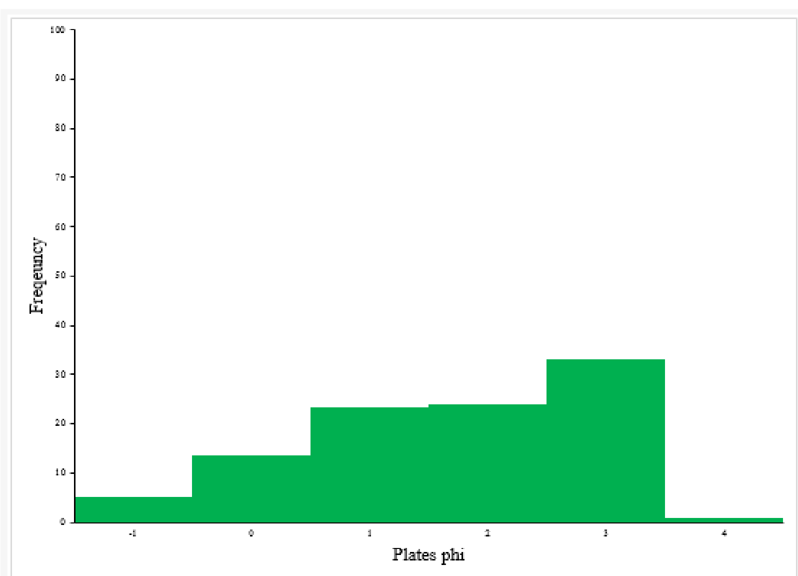

Figure B4. Frequency histogram of the particle grain size distribution for sample 1 from transect 2 in Añasco beach during sampling 1 (August/September 2016).

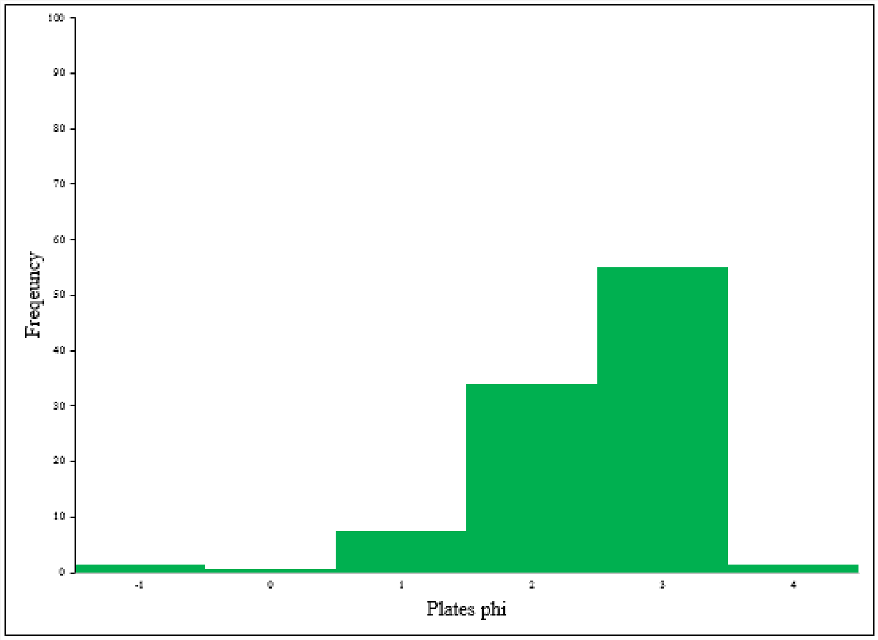

Figure B5. Frequency histogram of the particle grain size distribution for sample 4 from transect 2 in Añasco beach during sampling 1 (August/September 2016).

Table B6. Granulometry calculation for Transect 2, samples 1 and 4 at Añasco beach in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 2	-1	5.3	5.26
Sample 1	0	13.6	13.50
	1	23.4	23.23
	2	24.1	23.93
	3	33.3	33.06
	4	1	0.99
	Total	100.7	
Sample 4	-1	1.4	1.38
	0	0.6	0.59
	1	7.5	7.43
	2	34.4	34.09
	3	55.6	55.10
	4	1.4	1.38
	Total	100.9	

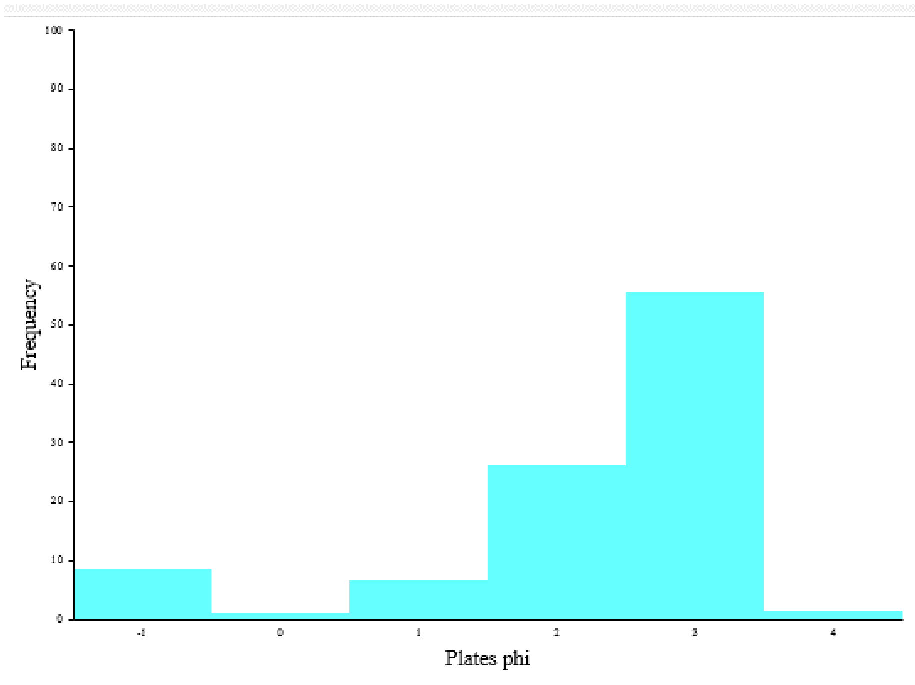

Figure B7. Frequency histogram of the particle grain size distribution for sample 1 from transect 3 in Añasco beach during sampling 1 (August/September 2016).

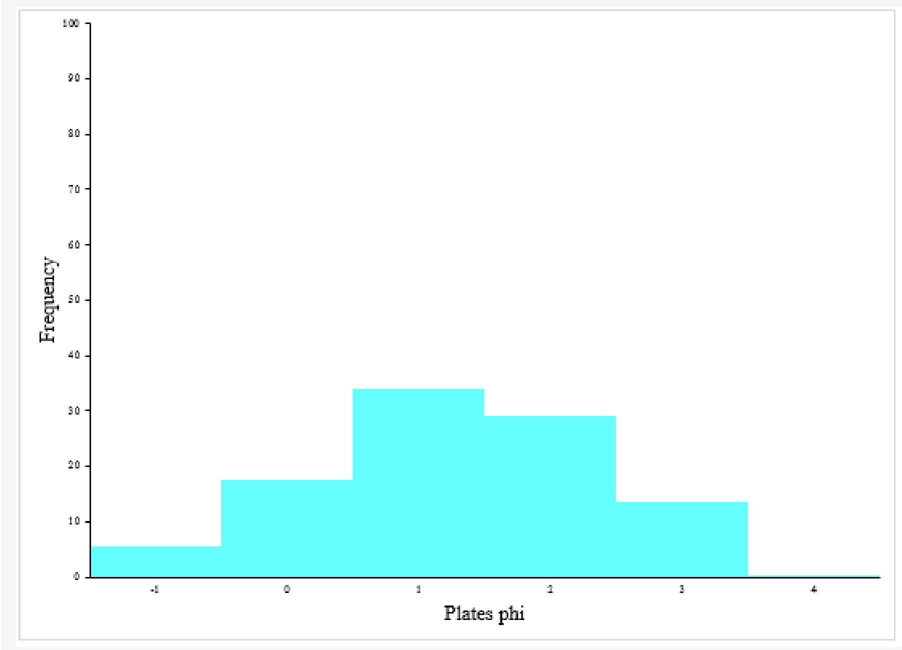

Figure B8. Frequency histogram of the particle grain size distribution for sample 4 from transect 3 in Añasco beach during sampling 1 (August/September 2016).

Table B9. Granulometry calculation for Transect 3, samples 1 and 4 at Añasco beach in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 3			
Sample 1	-1	9.5	8.80
	0	1.3	1.20
	1	7.3	6.76
	2	28.2	26.13
	3	60	55.60
	4	1.6	1.48
	Total	107.9	
Sample 4	-1	5.4	5.36
	0	17.7	17.57
	1	34.2	33.96
	2	29.2	28.99
	3	13.8	13.70
	4	0.4	0.39
	Total	100.7	

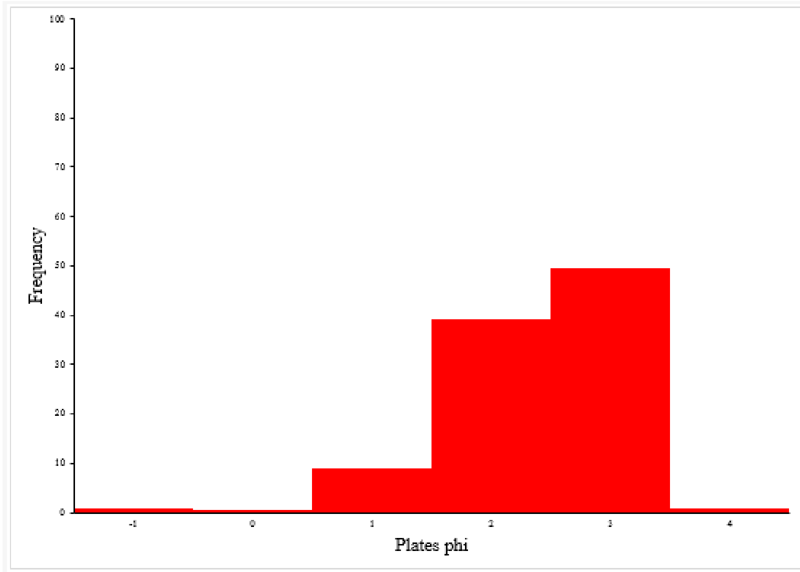

Figure B10. Frequency histogram of the particle grain size distribution for sample 1 from transect 4 in Añasco beach during sampling 1.

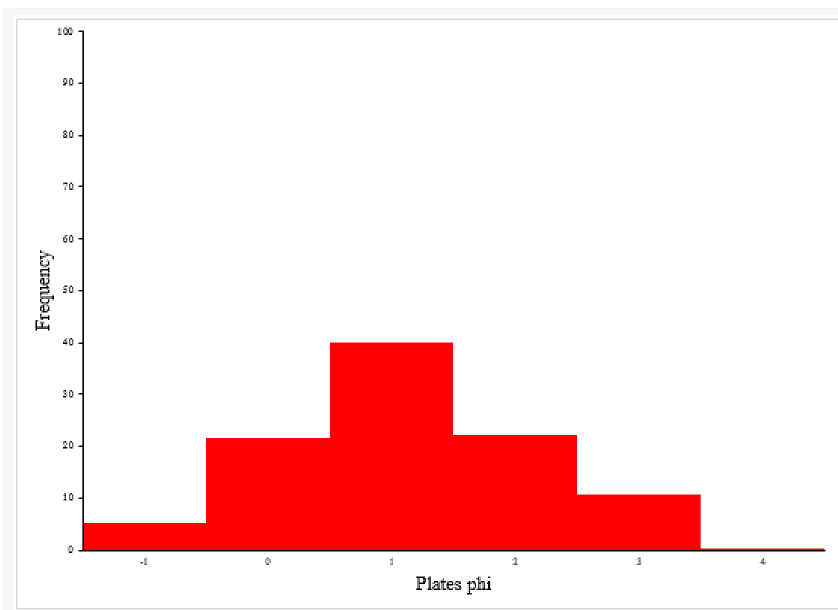

Figure B11. Frequency histogram of the particle grain size distribution for sample 4 from transect 4 in Añasco beach during sampling 1 (August/September 2016).

Table B12. Granulometry calculation for Transect 4, samples 1 and 4, at Añasco beach in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 4			
Sample 1	-1	1	0.99
	0	0.6	0.59
	1	8.9	8.89
	2	39.3	39.26
	3	49.5	49.45
	4	0.8	0.79
	Total	100.1	
Sample 4	-1	5.2	5.33
	0	21.1	21.66
	1	38.9	39.93
	2	21.5	22.07
	3	10.5	10.78
	4	0.2	0.20
	Total	97.4	

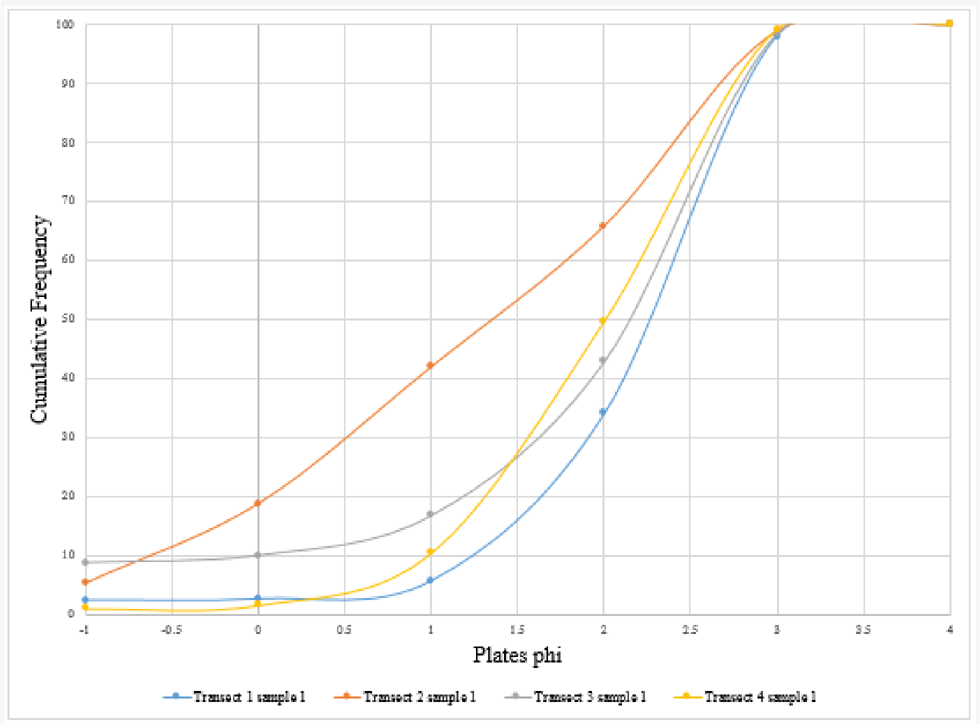

Figure B13. Cumulative frequency curve of the particle grain size distribution for sample 1 in all transects (T1, T2, T3, T4) at Añasco beach in sampling 1 (August/September 2016).

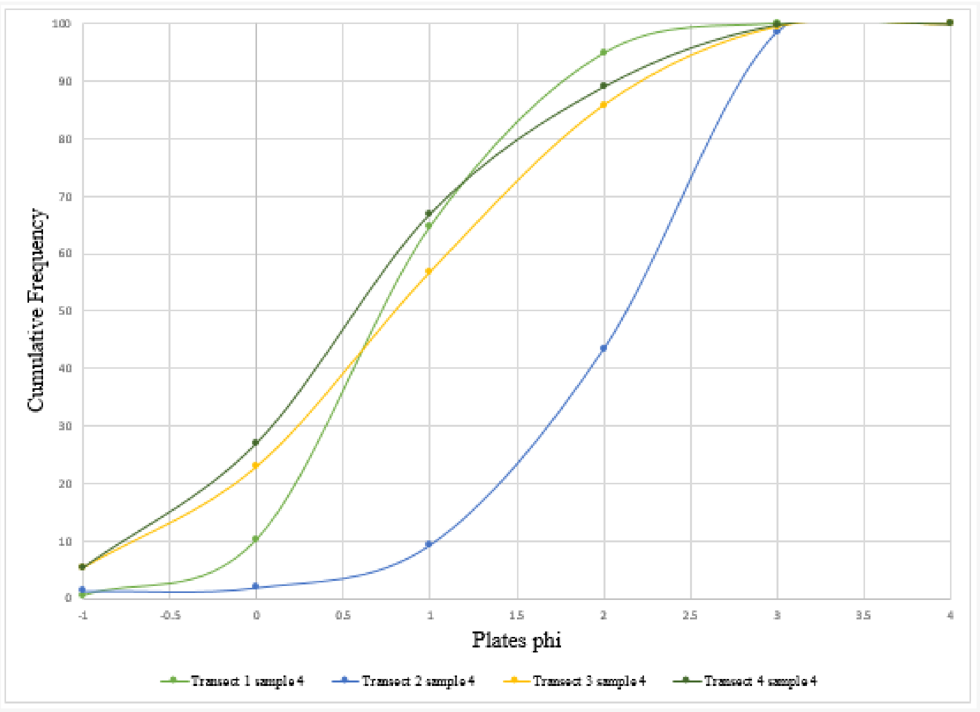

Figure B14. Cumulative frequency curve of the particle grain size distribution for sample 4 in all transects (T1, T2, T3, T4) at Añasco beach in sampling 1 (August/September 2016).

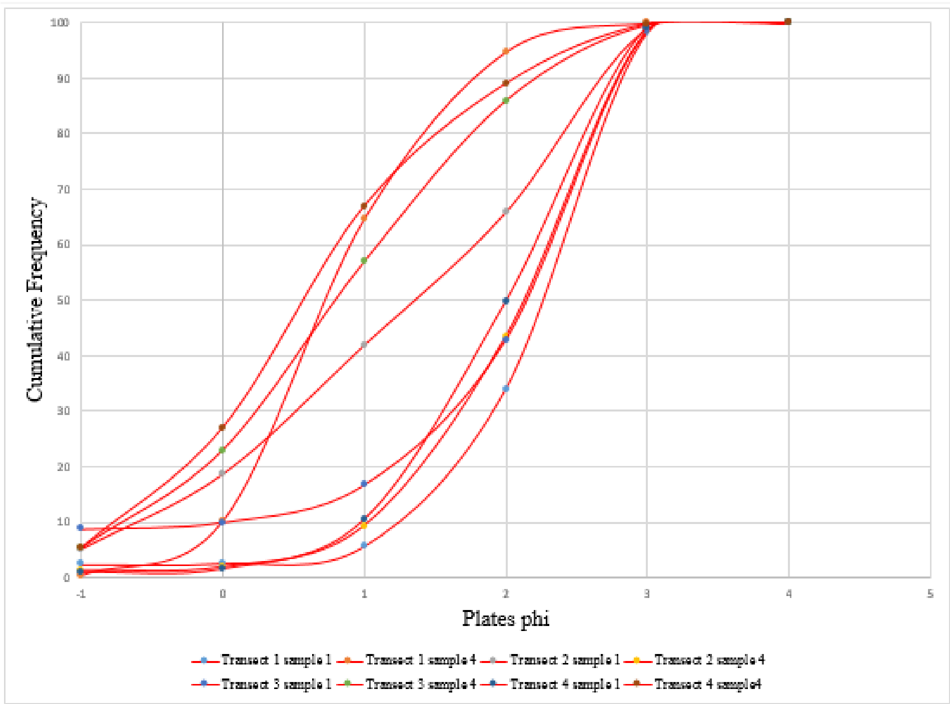

Figure B15. Cumulative frequency curve of the particle grain size distribution for all transects (T1, T2, T3, T4), samples 1 and 4, at Añasco beach in sampling 1 (August/September 2016).

Table B16. Granulometry calculation for all transects (T1,T2,T3,T4), samples 1 and 4, at Añasco beach in Sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency	Frequency
Transect 1			Cumulative curve	Histograms
Sample 1	-1	2.5	2.47	2.47
	0	0.2	2.67	0.19
	1	3.1	5.74	3.07
	2	28.6	34.09	28.34
	3	64.6	98.11	64.02
	4	1.9	100	1.88
	Total	100.9		
Sample 4	-1	0.5	0.51	0.51
	0	9.5	10.23	9.72
	1	53.2	64.68	54.45
	2	29.4	94.77	30.09
	3	5.1	100	5.22

	4	0	100	0
	Total	97.7		
Transect 2				
Sample 1	-1	5.3	5.263	5.263
	0	13.6	18.76	13.50
	1	23.4	42.00	23.23
	2	24.1	65.93	23.93
	3	33.3	99.00	33.06
	4	1	100	0.99
	Total	100.7		
Sample 4	-1	1.4	1.387	1.38
	0	0.6	1.98	0.59
	1	7.5	9.41	7.43
	2	34.4	43.50	34.09
	3	55.6	98.61	55.10
	4	1.4	100	1.38
	Total	100.9		
Transect 3				
Sample 1	-1	9.5	8.80	8.80
	0	1.3	10.00	1.20
	1	7.3	16.77	6.76
	2	28.2	42.91	26.13
	3	60	98.51	55.60
	4	1.6	100	1.48
	Total	107.9		
Sample 4	-1	5.4	5.36	5.36
	0	17.7	22.93	17.57
	1	34.2	56.90	33.96

	2	29.2	85.89	28.99
	3	13.8	99.60	13.70
	4	0.4	100	0.39
	Total	100.7		
Transect 4				
Sample 1	-1	1	0.99	0.99
	0	0.6	1.59	0.59
	1	8.9	10.48	8.89
	2	39.3	49.75	39.26
	3	49.5	99.20	49.45
	4	0.8	100	0.79
	Total	100.1		
Sample 4	-1	5.2	5.33	5.33
	0	21.1	27.00	21.66
	1	38.9	66.94	39.93
	2	21.5	89.01	22.07
	3	10.5	99.79	10.78
	4	0.2	100	0.20
	Total	97.4		

Appendix C

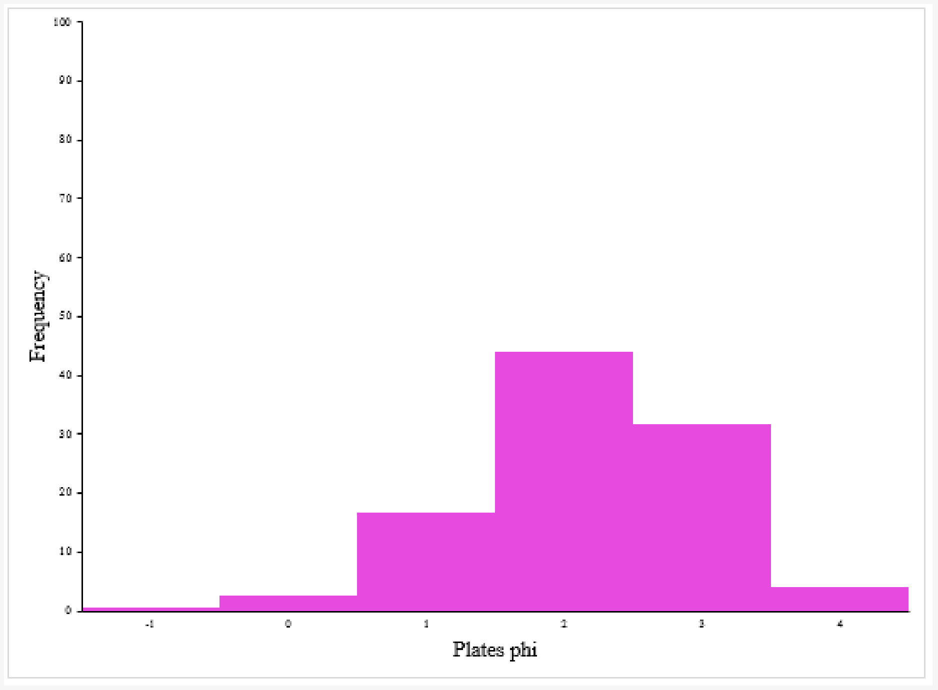

Figure C1. Frequency histogram of the particle grain size distribution for sample 1 from transect 1 in Rincón beach during sampling 1.

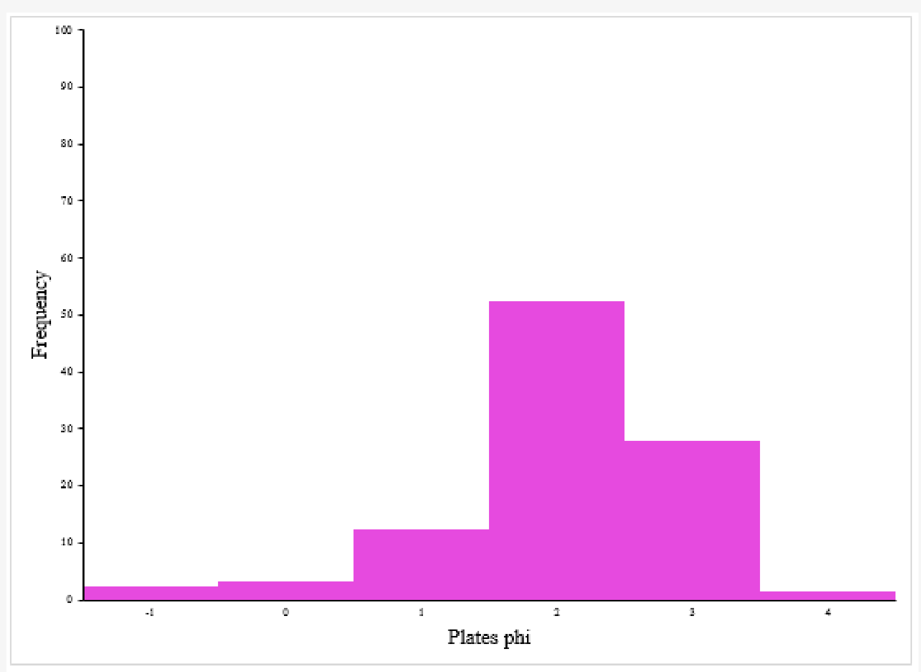

Figure C2. Frequency histogram of the particle grain size distribution for sample 4 from transect 1 in Rincón beach during sampling 1 (August/September 2016).

Table C3. Granulometry calculation for histograms for Transect 1, samples 1 and 4 at Rincón in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 1			
Sample 1	-1	0.6	0.6
	0	2.5	2.6
	1	16.2	16.8
	2	42.6	44.1
	3	30.7	31.8
	4	3.9	4.0
	Total	96.5	
Sample 4	-1	2.4	2.44
	0	3.2	3.3
	1	12.2	12.4
	2	51.4	52.4
	3	27.4	27.9
	4	1.4	1.4
	Total	98	

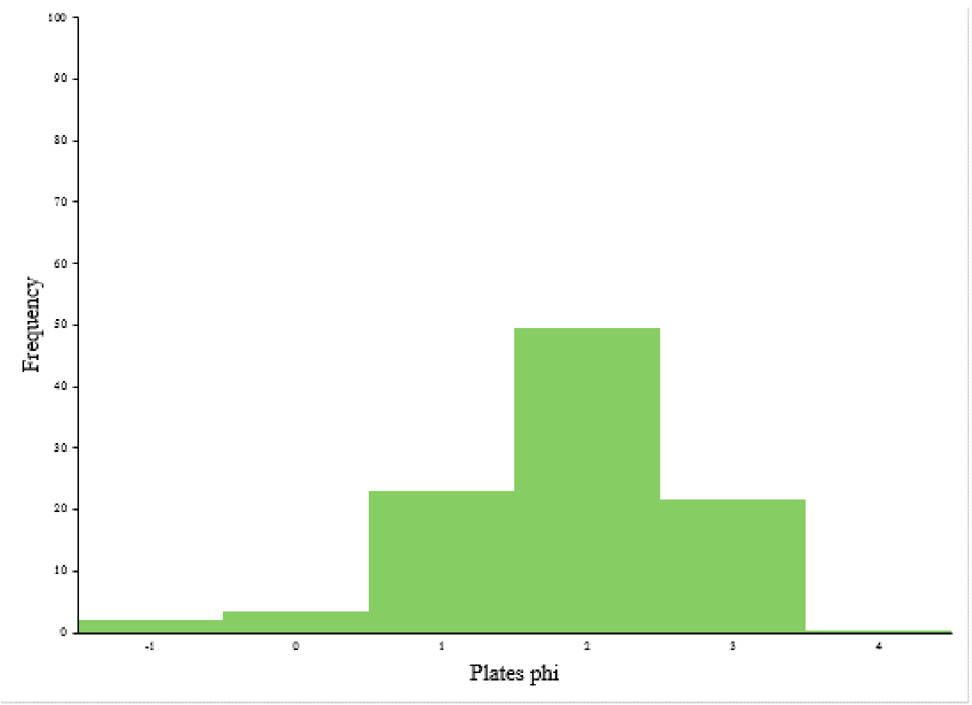

Figure C4. Frequency histogram of the particle grain size distribution for sample 1 from transect 2 in Rincón beach during sampling 1.

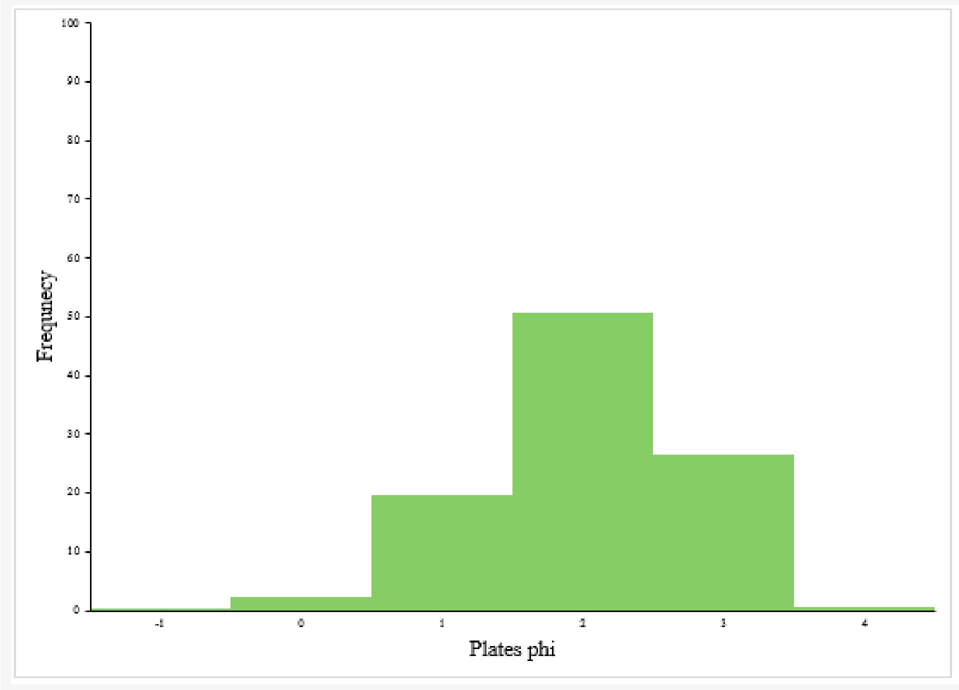

Figure C5. Frequency histogram of the particle grain size distribution for sample 4 from transect 2 in Rincón beach during sampling 1.

Table C6. Granulometry calculation for histograms of Transect 2, samples 1 and 4, at Rincón in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 2			
Sample 1	-1	2.1	2.1
	0	3.5	3.5
	1	22.9	23.0
	2	49.2	49.5
	3	21.4	21.5
	4	0.3	0.3
	Total	99.4	
Sample 4	-1	0.3	0.3
	0	2.2	2.2
	1	19.4	19.7
	2	49.8	50.6
	3	26.2	26.6
	4	0.5	0.5
	Total	98.4	

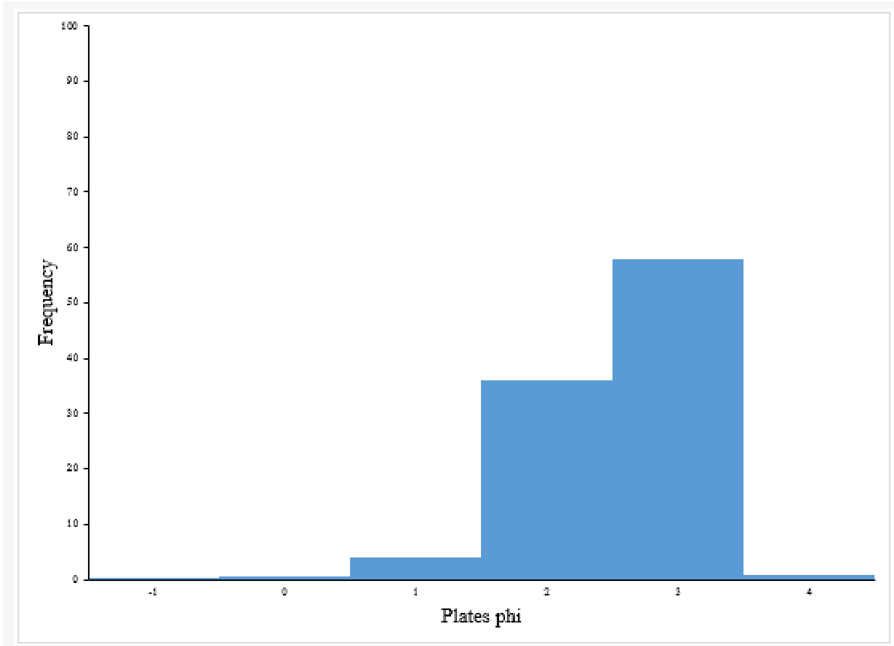

Figure C7. Frequency histogram of the particle grain size distribution for sample 1 from transect 3 in Rincón beach during sampling 1 (August/September 2016).

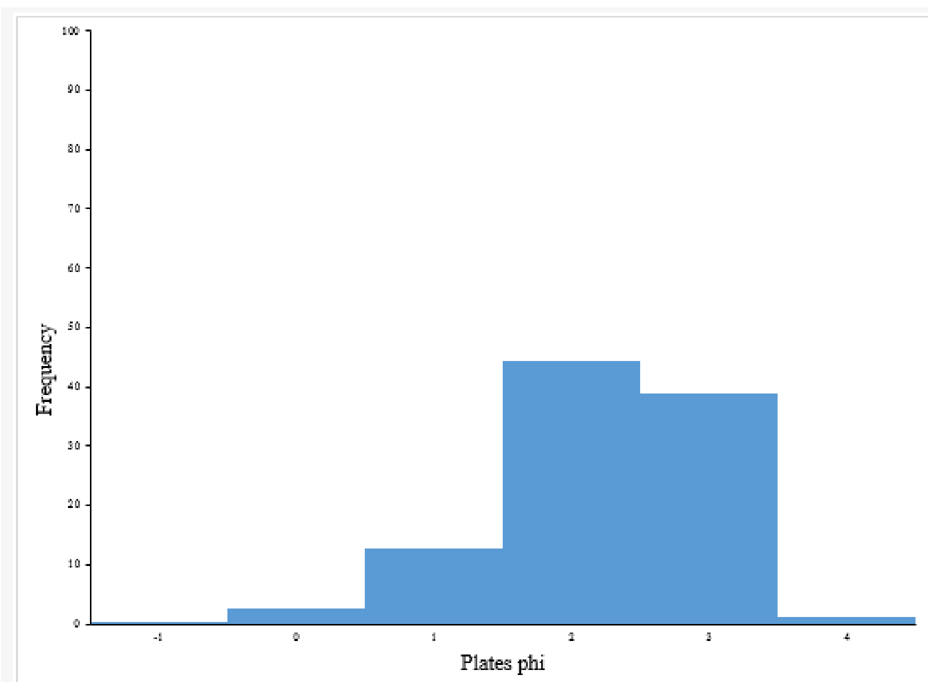

Figure C8. Frequency histogram of the particle grain size distribution for sample 4 from transect 3 in Rincón beach during sampling 1.

Table C9. Granulometry calculation for histograms of Transect 3, samples 1 and 4 at Rincón in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 3			
Sample 1	-1	0.1	0.1
	0	0.6	0.6
	1	4.1	4.2
	2	35.5	36.1
	3	57	57.9
	4	1	1.0
	Total	98.3	
Sample 4	-1	0.3	0.3
	0	2.7	2.7
	1	12.4	12.6
	2	43.9	44.5
	3	38.3	38.8
	4	1.1	1.1
	Total	98.7	

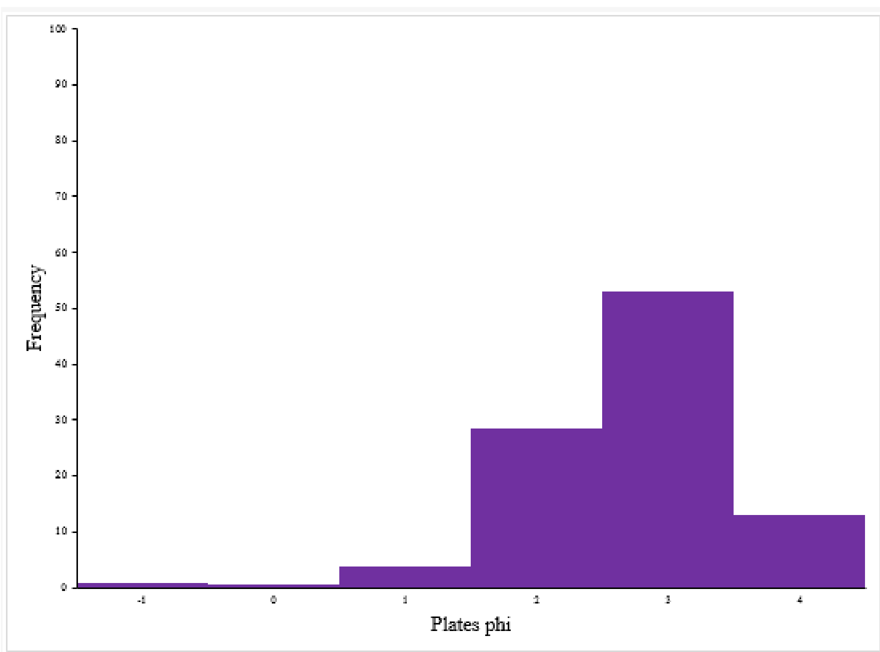

Figure C10. Frequency histogram of the particle grain size distribution for sample 1 from transect 4 in Rincón beach during sampling 1 (August/September 2016).

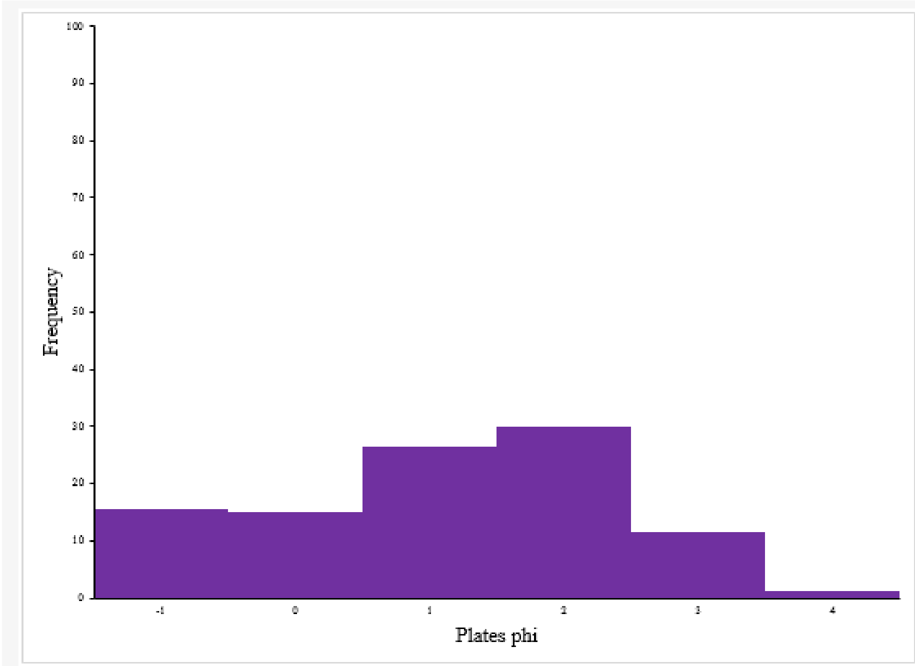

Figure C11. Frequency histogram of the particle grain size distribution for sample 4 from transect 4 in Rincón beach during sampling 1 (August/September 2016).

Table C12. Granulometry calculation for histograms of Transect 4, samples 1 and 4 at Rincón in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 4			
Sample 1	-1	1	1.0
	0	0.6	0.6
	1	3.8	3.8
	2	28.5	28.6
	3	52.9	53.0
	4	12.9	12.9
	Total	99.7	
Sample 4	-1	16.3	15.6
	0	15.8	15.1
	1	27.8	26.6
	2	31.2	29.9
	3	12.1	11.6
	4	1.2	1.1
	Total	104.4	

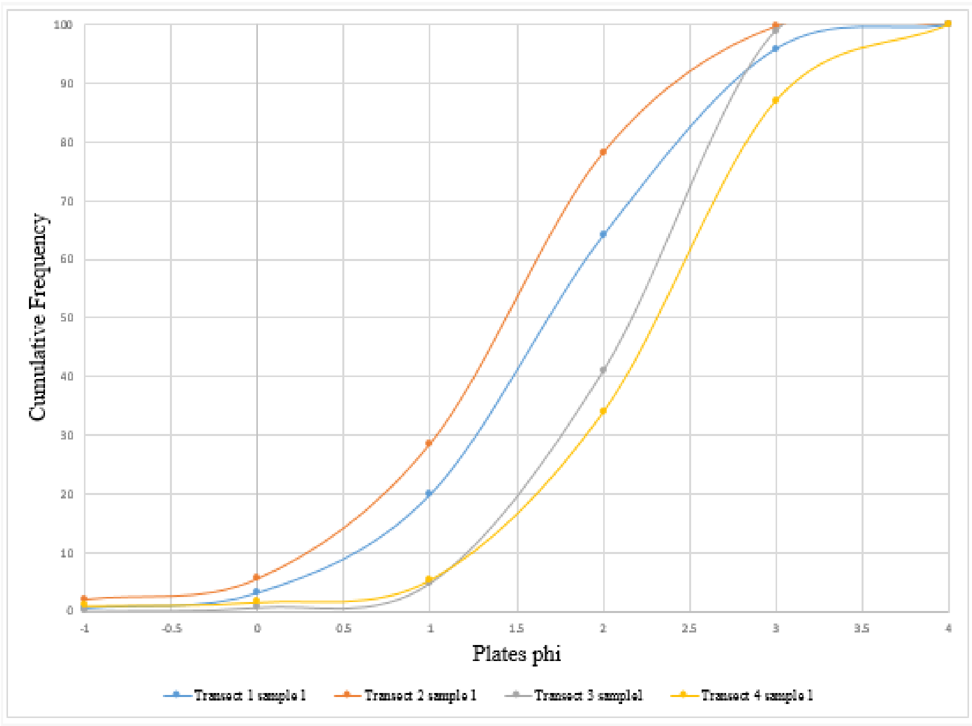

Figure C13. Cumulative frequency curve of the particle grain size distribution for sample 1 in all transects (T1, T2, T3, T4) at Rincón beach in sampling 1 (August/September 2016).

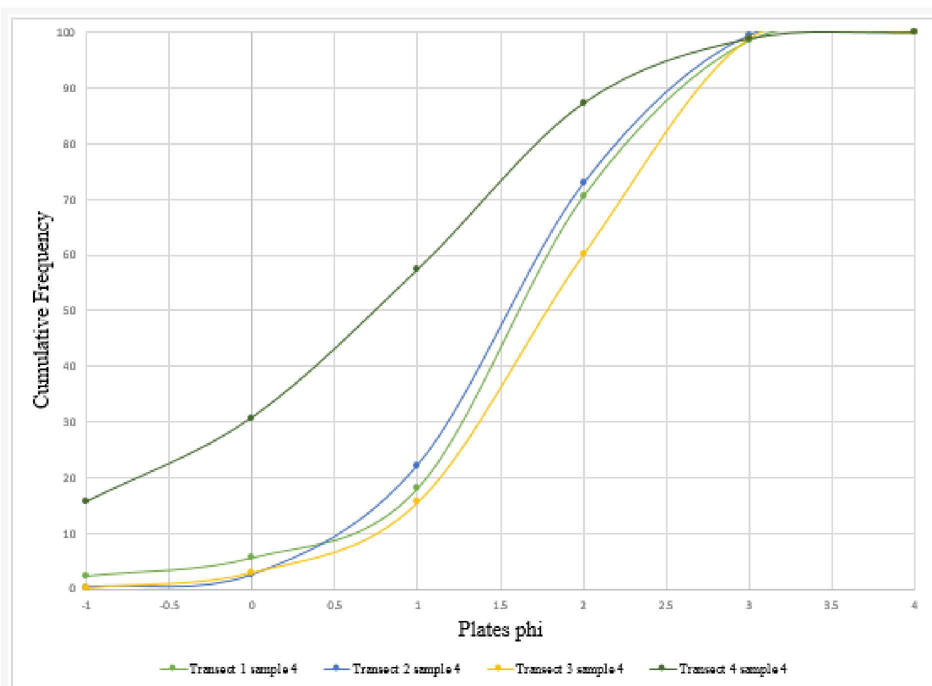

Figure C14. Cumulative frequency curve of the particle grain size distribution for sample 4 in all transects (T1, T2, T3, T4) at Rincón beach in sampling 1 (August/September 2016).

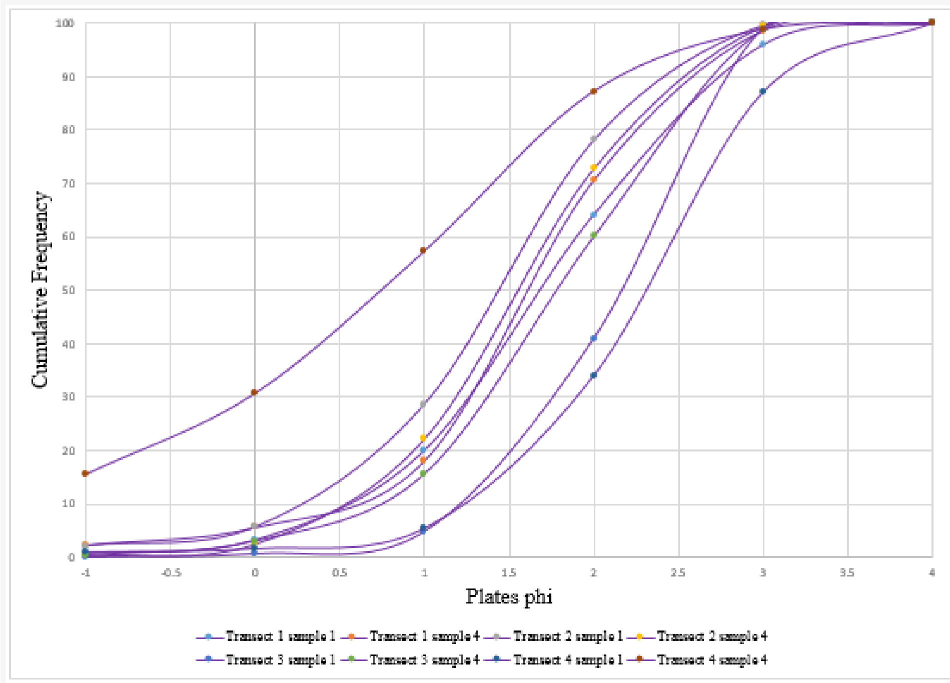

Figure C15. Cumulative frequency curve of the particle grain size distribution for all transects (T1, T2, T3, T4) in samples 1 and 4 at Rincón beach in sampling 1 (August/September 2016).

Table C16. Granulometry calculation of cumulative frequency for all transects (T1, T2, T3, T4) in samples 1 and 4 at Rincón in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency	Frequency
Transect 1			Cumulative curve	Histograms
Sample 1	-1	0.6	0.6	0.6
	0	2.5	3.2	2.6
	1	16.2	20	16.8
	2	42.6	64.1	44.1
	3	30.7	95.9	31.8
	4	3.9	100	4.0
	Total	96.5		
Sample 4	-1	2.4	2.4	2.4
	0	3.2	5.7	3.3
	1	12.2	18.1	12.4
	2	51.4	70.6	52.4
	3	27.4	98.6	27.9
	4	1.4	100	1.4
	Total	98		
Transect 2				
Sample 1	-1	2.1	2.1	2.1

	0	3.5	5.6	3.5
	1	22.9	28.7	23.0
	2	49.2	78.2	49.5
	3	21.4	99.7	21.5
	4	0.3	100	0.3
	Total	99.4		
Sample 4	-1	0.3	0.3	0.3
	0	2.2	2.5	2.2
	1	19.4	22.2	19.7
	2	49.8	72.9	50.6
	3	26.2	99.5	26.6
	4	0.5	100	0.5
	Total	98.4		
Transect 3				
Sample 1	-1	0.1	0.1	0.1
	0	0.6	0.7	0.6
	1	4.1	4.9	4.2
	2	35.5	40.9	36.1
	3	57	98.9	57.9
	4	1	100	1.0
	Total	98.3		
Sample 4	-1	0.3	0.3	0.3
	0	2.7	3.0	2.7
	1	12.4	15.6	12.6
	2	43.9	60.1	44.5
	3	38.3	98.9	38.8
	4	1.1	100	1.1
	Total	98.7		
Transect 4				
Sample 1	-1	1	1.0	1.0
	0	0.6	1.6	0.6
	1	3.8	5.4	3.8
	2	28.5	34.0	28.6
	3	52.9	87.1	53.0
	4	12.9	100	12.9
	Total	99.7		
Sample 4	-1	16.3	15.6	15.6
	0	15.8	30.7	15.1
	1	27.8	57.4	26.6
	2	31.2	87.3	29.9
	3	12.1	98.8	11.6

	4	1.2	100	1.1
	Total	104.4		

Appendix D

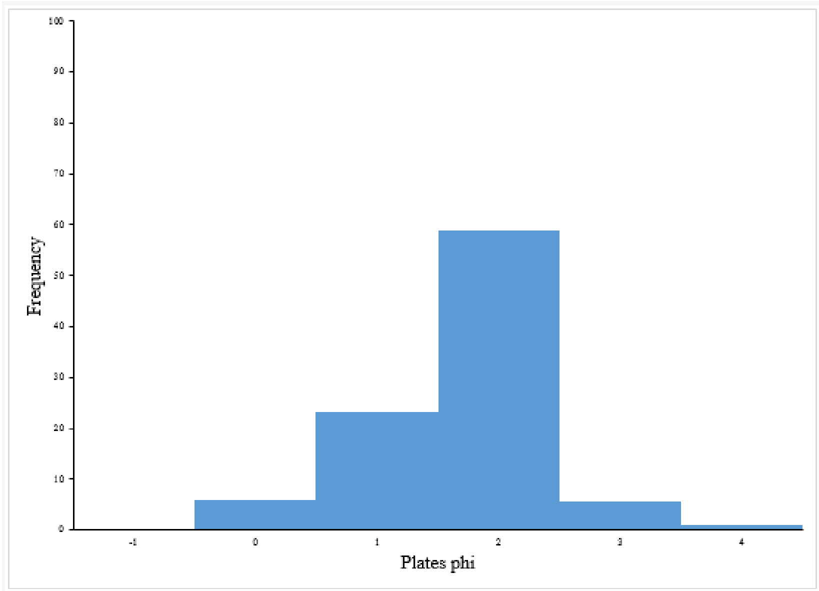

Figure D1. Frequency histogram of the particle grain size distribution for sample 1 from transect 1 in Cabo Rojo beach during sampling 1.

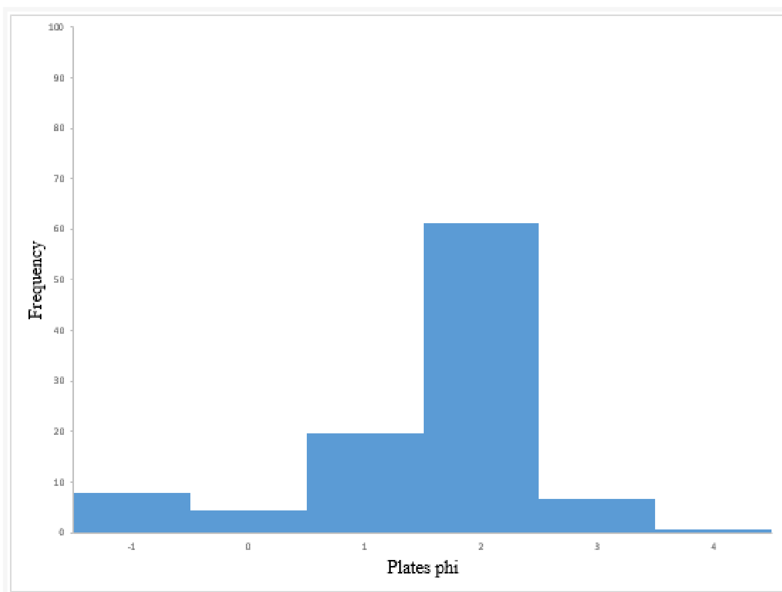

Figure D2. Frequency histogram of the particle grain size distribution for sample 2 from transect 1 in Cabo Rojo beach during sampling 1 (August/September 2016).

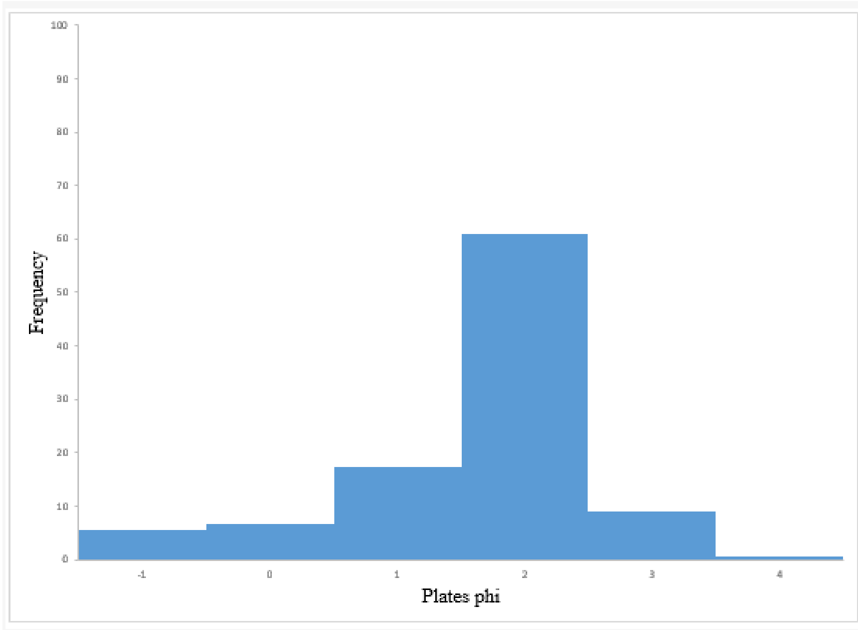

Figure D3. Frequency histogram of the particle grain size distribution for sample 3 from transect 1 in Cabo Rojo beach during sampling 1 (August/September 2016).

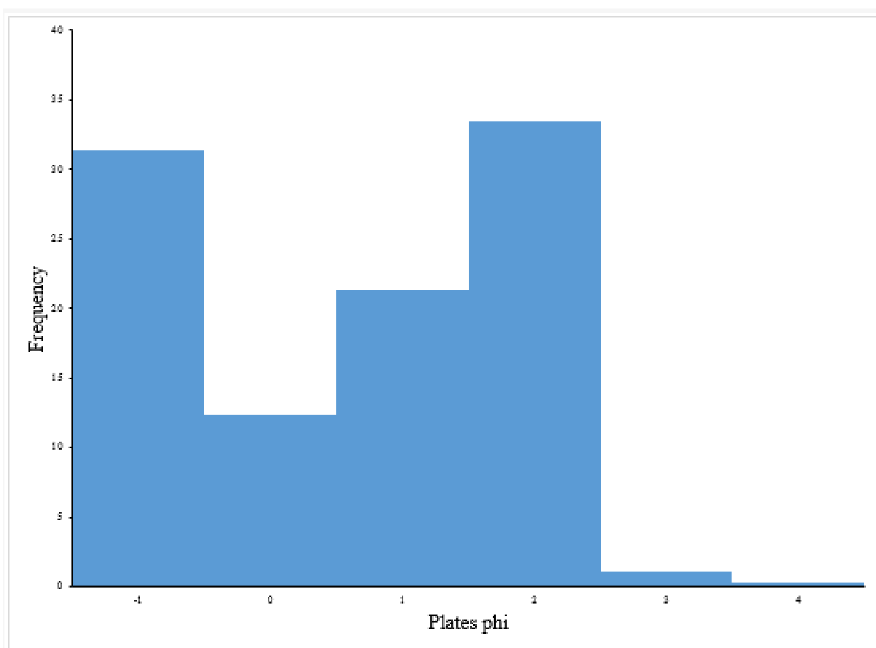

Figure D4. Frequency histogram of the particle grain size distribution for sample 4 from transect 1 in Cabo Rojo beach during sampling 1 (August/September 2016).

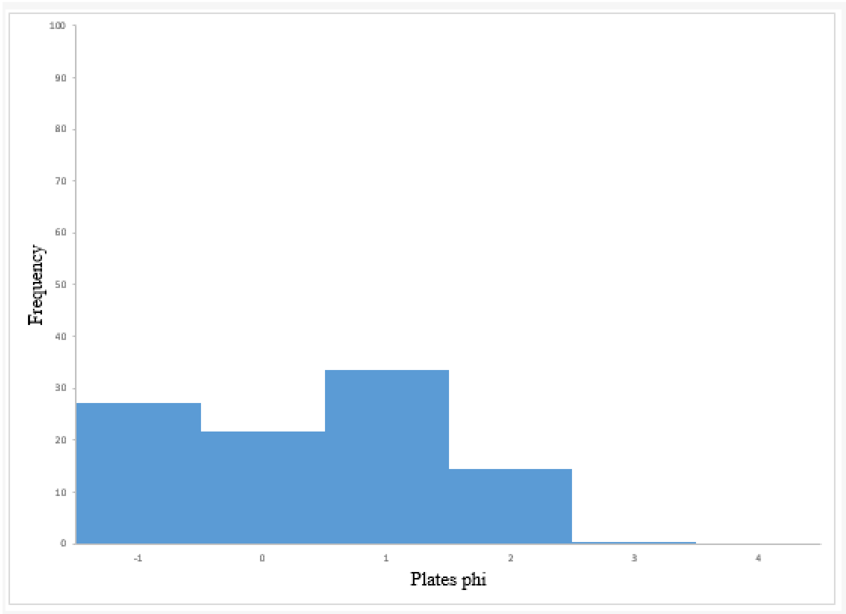

Figure D5. Frequency histogram of the particle grain size distribution for sample 5 from transect 1 in Cabo Rojo beach during sampling 1 (August/September 2016).

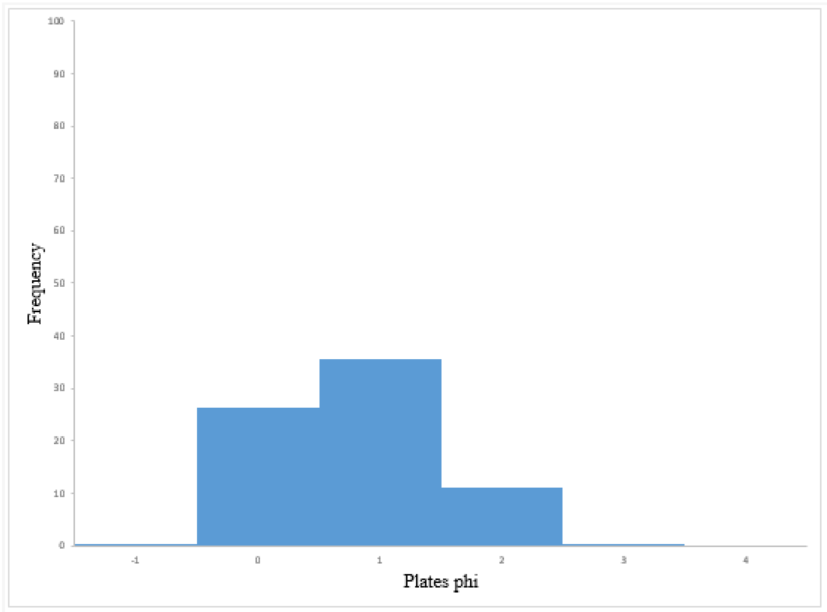

Figure D6. Frequency histogram of the particle grain size distribution for sample 6 from transect 1 in Cabo Rojo beach during sampling 1 (August/September 2016).

Table D7. Granulometry calculation for histograms of Transect 1 with samples (1,2,3,4,5,6) at Cabo Rojo in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 1			
Sample 1	-1	19.8	18.9
	0	14.3	13.7
	1	29.8	28.6
	2	38.1	36.5
	3	2	1.9
	4	0.4	0.4
	Total	104.3	
Sample 2	-1	15.1	13.94
	0	17.3	29.91
	1	25.1	67.67
	2	47.3	104.05
	3	2.9	106.72
	4	0.6	107.27
	Total	108.3	
Sample 3	-1	23.9	22.87
	0	14.6	36.84
	1	25.1	60.85
	2	39.4	98.55
	3	1.3	99.79
	4	0.4	100.17
	Total	104.5	
Sample 4	-1	37	31.4
	0	14.6	12.4
	1	25.1	21.3
	2	39.4	33.4
	3	1.3	1.1
	4	0.4	0.3
	Total	117.8	

Sample 5	-1	35	34.11
	0	21.7	55.26
	1	28.1	82.64
	2	17	99.2
	3	0.2	99.39
	4	0	99.39
	Total	102.6	
Sample 6	-1	26.2	26.65
	0	21.6	48.62
	1	27	76.08
	2	22.9	99.37
	3	0.6	99.98
	4	0	100.07
	Total	98.3	

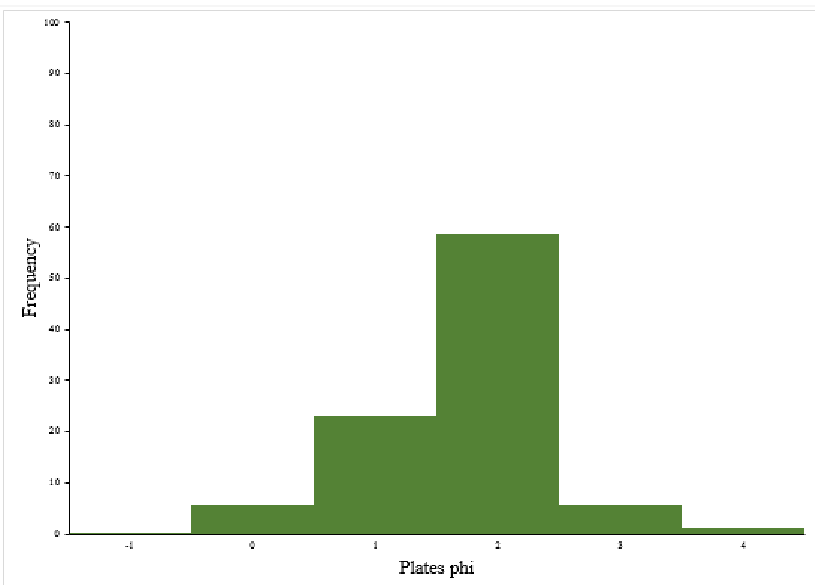

Figure D8. Frequency histogram of the particle grain size distribution for sample 1 from transect 2 in Cabo Rojo beach during sampling 1 (August/September 2016).

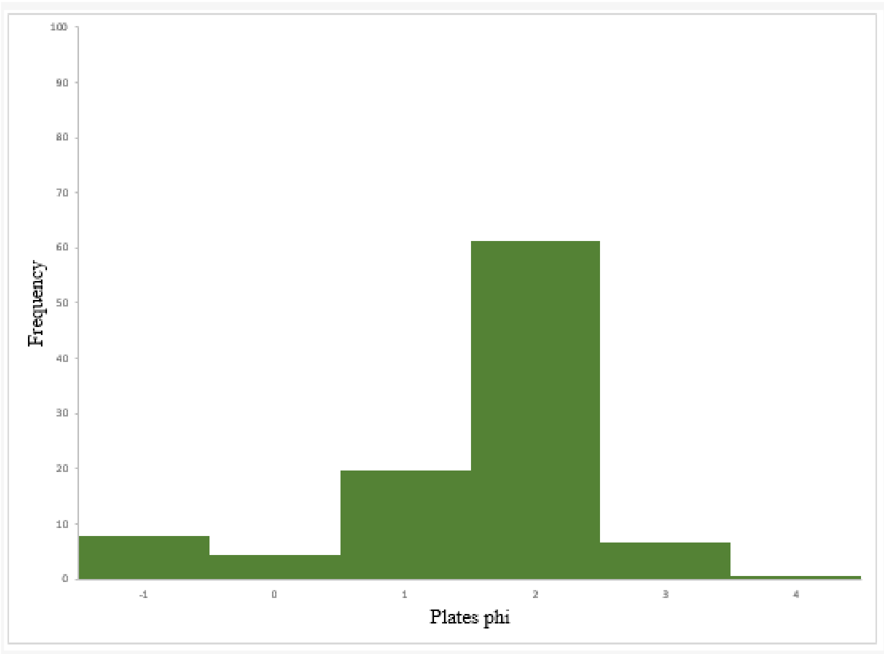

Figure D9. Frequency histogram of the particle grain size distribution for sample 2 from transect 2 in Cabo Rojo beach during sampling 1.

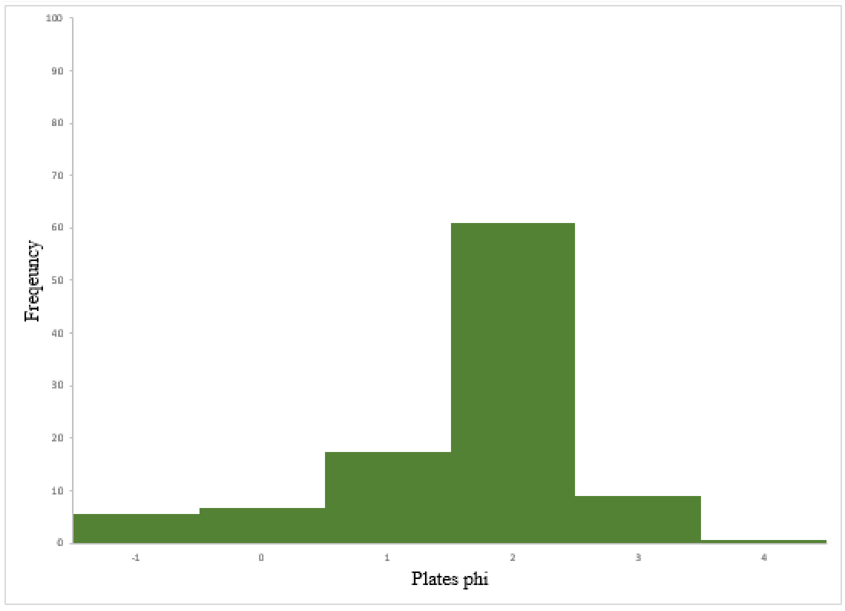

Figure D10. Frequency histogram of the particle grain size distribution for sample 3 from transect 2 in Cabo Rojo beach during sampling 1 (August/September 2016).

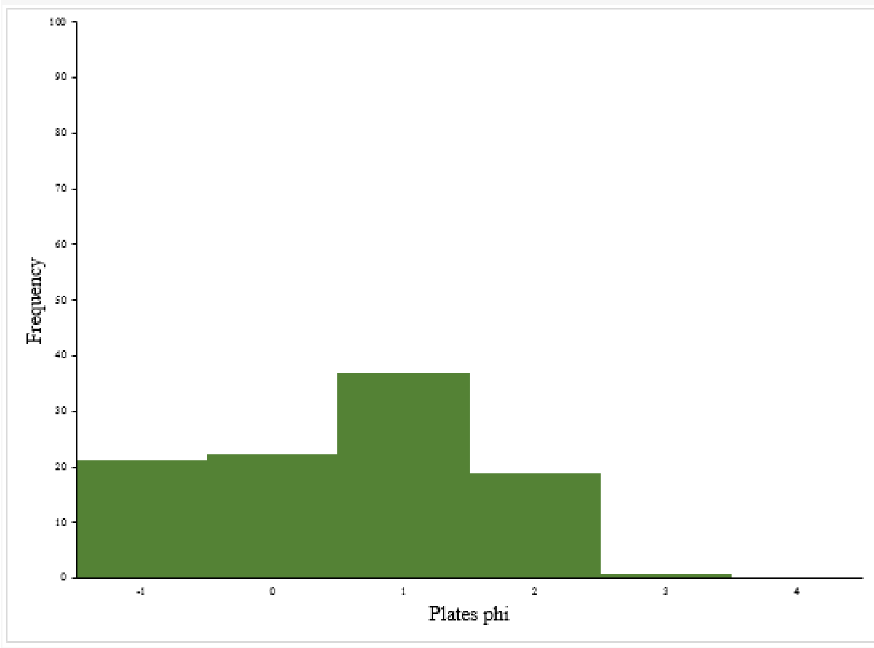

Figure D11. Frequency histogram of the particle grain size distribution for sample 4 from transect 2 in Cabo Rojo beach during sampling 1 (August/September 2016).

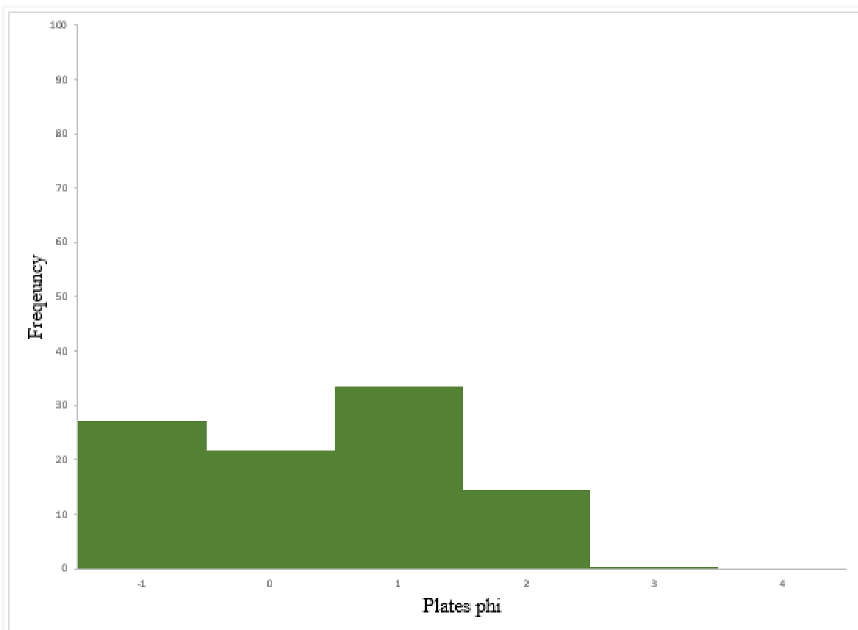

Figure D12. Frequency histogram of the particle grain size distribution for sample 5 from transect 2 in Cabo Rojo beach during sampling 1 (August/September 2016).

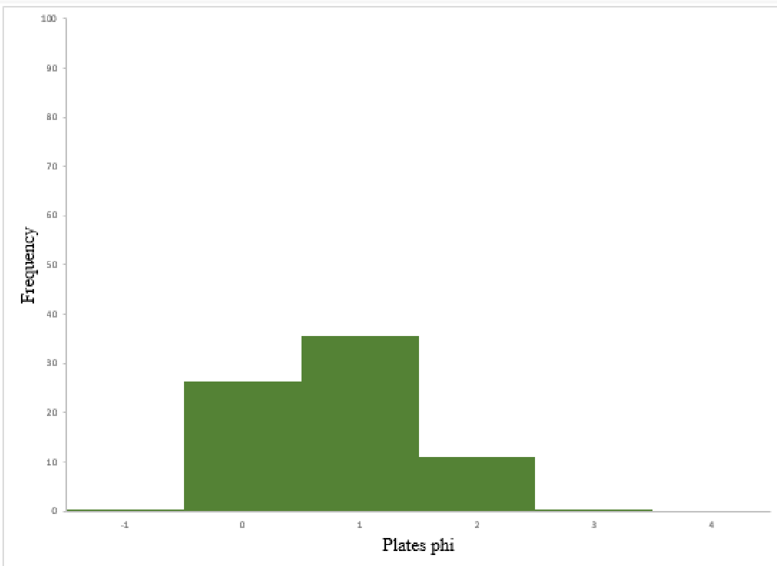

Figure D13. Frequency histogram of the particle grain size distribution for sample 6 from transect 2 in Cabo Rojo beach during sampling 1 (August/September 2016).

Table D14. Granulometry calculation for histograms of Transect 2 with all samples (1,2,3,4,5,6) at Cabo Rojo in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 2			
Sample 1	-1	5.4	0.05
	0	5.9	5.9
	1	23.2	23.1
	2	59.2	58.8
	3	5.8	5.8
	4	1.1	1.1
	Total	100.6	
Sample 2	-1	15	15.1
	0	16	31.21
	1	26.1	57.49
	2	38.9	96.66
	3	2.8	99.47
	4	0.5	99.98
	Total	99.3	9.18

Sample 3	-1	9	23.15
	0	13.7	49.06
	1	25.4	96.10
	2	46.1	99.57
	3	3.4	99.98
	4	0.4	9.18
	Total	98	
Sample 4	-1	21.4	21.1
	0	22.7	22.4
	1	37.4	36.8
	2	19.2	18.9
	3	0.7	0.7
	4	0.1	0.1
	Total	101.5	
Sample 5	-1	10.6	10.64
	0	14.9	25.59
	1	32.5	58.22
	2	38	96.37
	3	3.1	99.48
	4	0.5	99.98
	Total	99.6	
Sample 6	-1	12.8	12.67
	0	22.5	34.94
	1	34.3	68.9
	2	30.6	99.19
	3	0.8	99.98
	4	0	100.28
	Total	101	

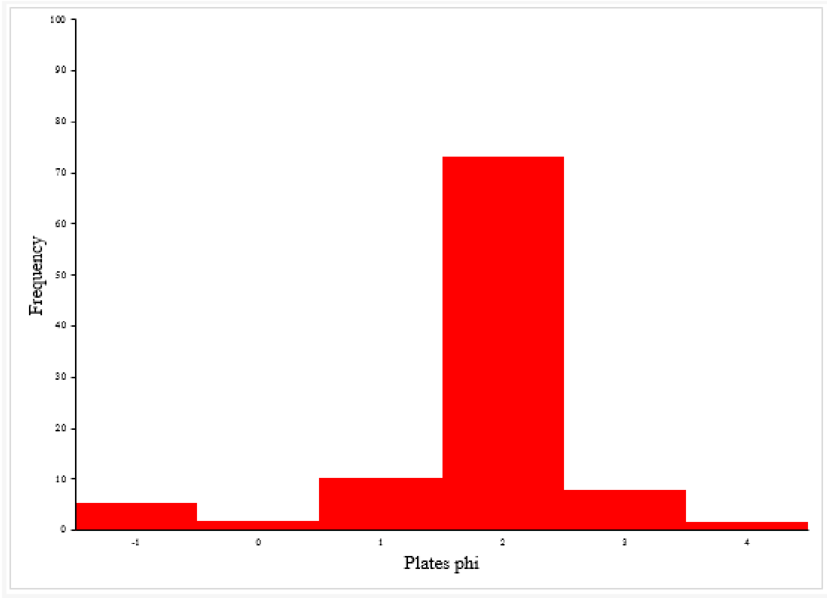

Figure D15. Frequency histogram of the particle grain size distribution for sample 1 from transect 3 in Cabo Rojo beach during sampling 1 (August/September 2016).

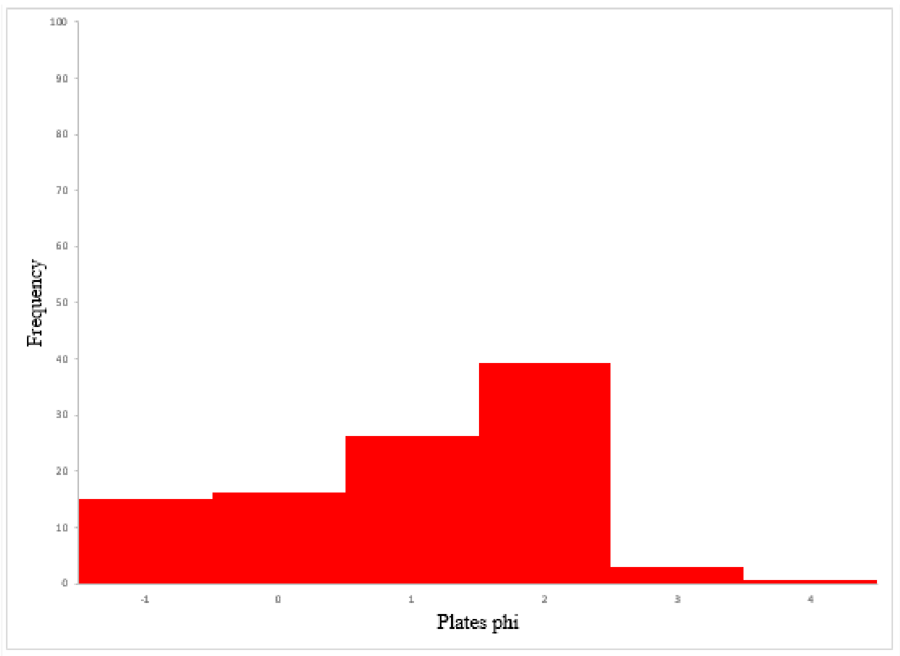

Figure D16. Frequency histogram of the particle grain size distribution for sample 2 from transect 3 in Cabo Rojo beach during sampling 1 (August/September 2016).

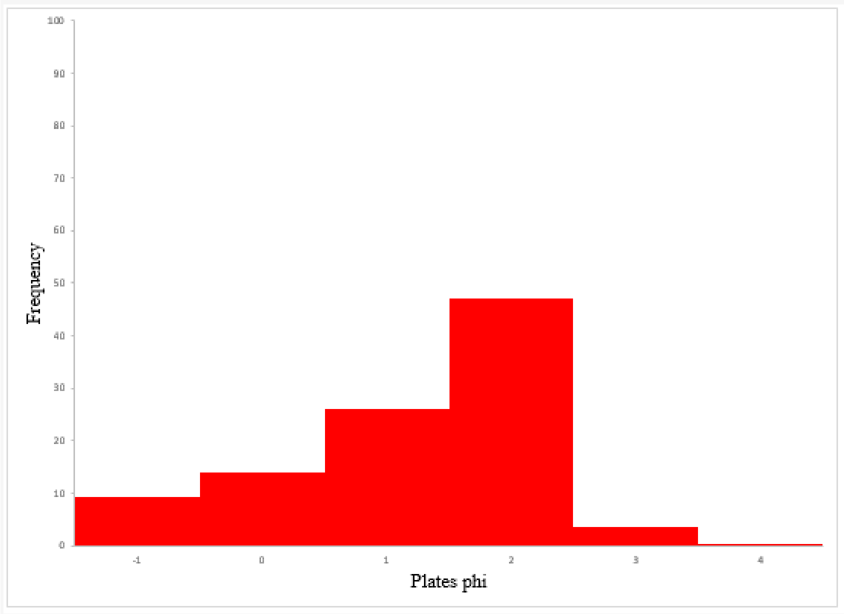

Figure D17. Frequency histogram of the particle grain size distribution for sample 3 from transect 3 in Cabo Rojo beach during sampling 1 (August/September 2016).

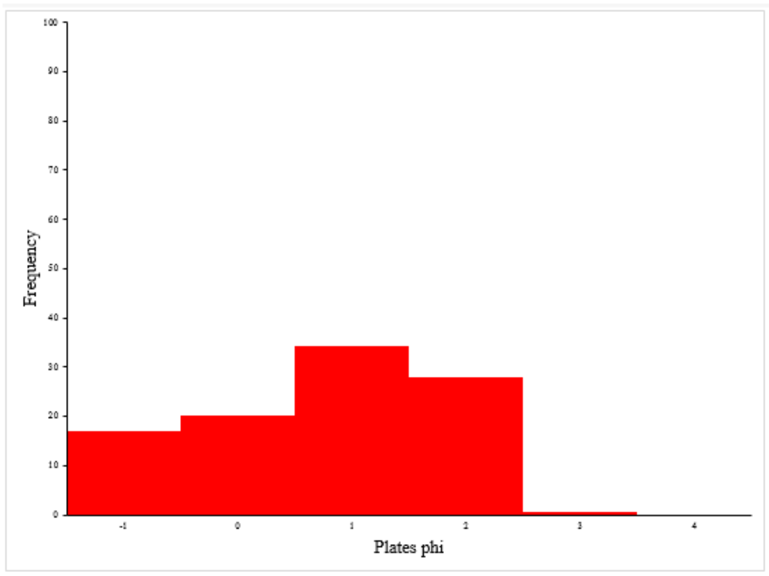

Figure D18. Frequency histogram of the particle grain size distribution for sample 4 from transect 3 in Cabo Rojo beach during sampling 1 (August/September 2016).

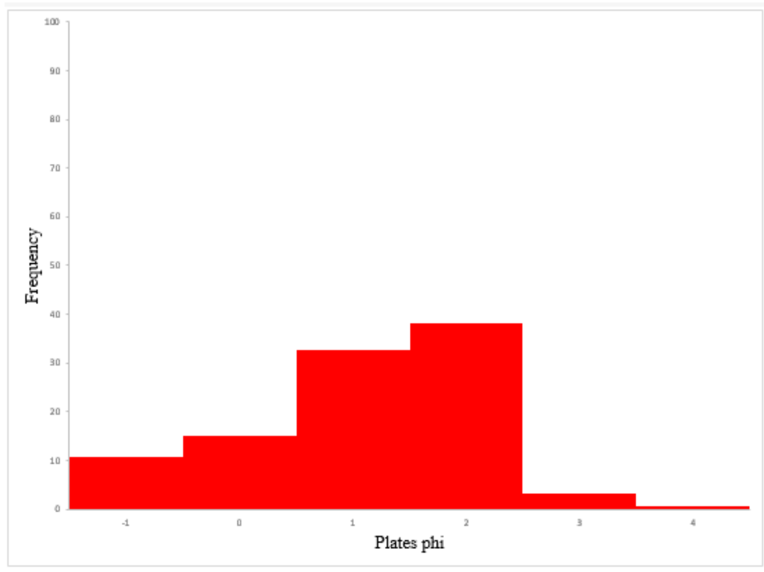

Figure D19. Frequency histogram of the particle grain size distribution for sample 5 from transect 3 in Cabo Rojo beach during sampling 1 (August/September 2016).

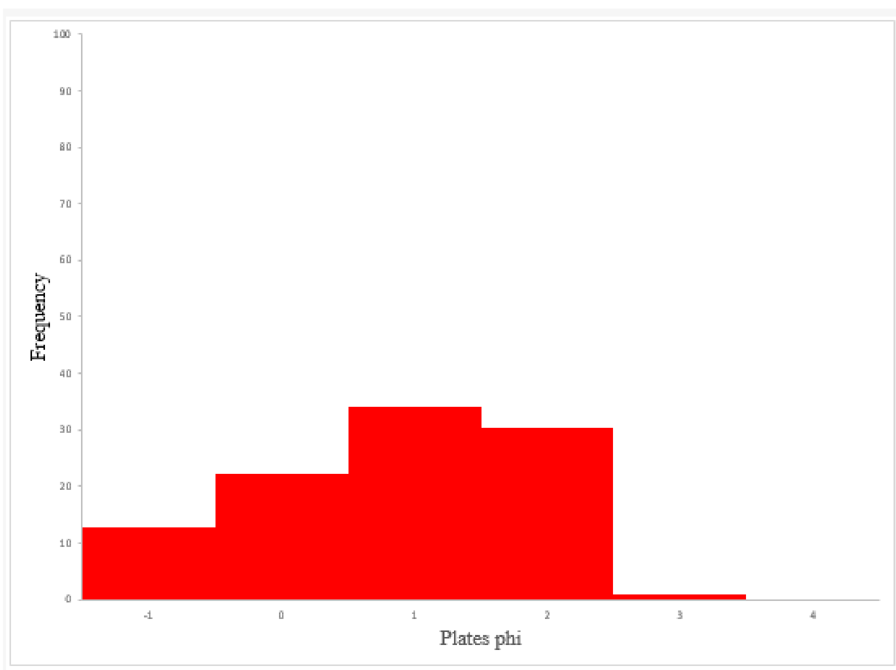

Figure D20. Frequency histogram of the particle grain size distribution for sample 6 from transect 3 in Cabo Rojo beach during sampling 1 (August/September 2016).

Table D21. Granulometry calculation for histograms of Transect 3 with all samples (1,2,3,4,5,6) at Cabo Rojo in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 3			
Sample 1	-1	5.3	5.3
	0	1.8	1.8
	1	10.1	10.1
	2	72.9	73.3
	3	7.8	7.8
	4	1.6	1.6
	Total	99.5	
Sample 2	-1	15	15.1
	0	16	31.21
	1	26.1	57.49
	2	38.9	96.66
	3	2.8	99.47
	4	0.5	99.98
	Total	99.3	
Sample 3	-1	9	9.18
	0	13.7	23.15
	1	25.4	49.06
	2	46.1	96.10
	3	3.4	99.57
	4	0.4	99.98
	Total	98	
Sample 4	-1	16.6	16.9
	0	19.9	20.3
	1	33.6	34.3
	2	27.3	27.8
	3	0.6	0.6
	4	0	0
	Total	98	
Sample 5	-1	10.6	10.64

	0	14.9	25.59
	1	32.5	58.22
	2	38	96.37
	3	3.1	99.48
	4	0.5	99.98
	Total	99.6	
Sample 6	-1	12.8	12.67
	0	22.5	34.94
	1	34.3	68.9
	2	30.6	99.19
	3	0.8	99.98
	4	0	100.28
	Total	101	

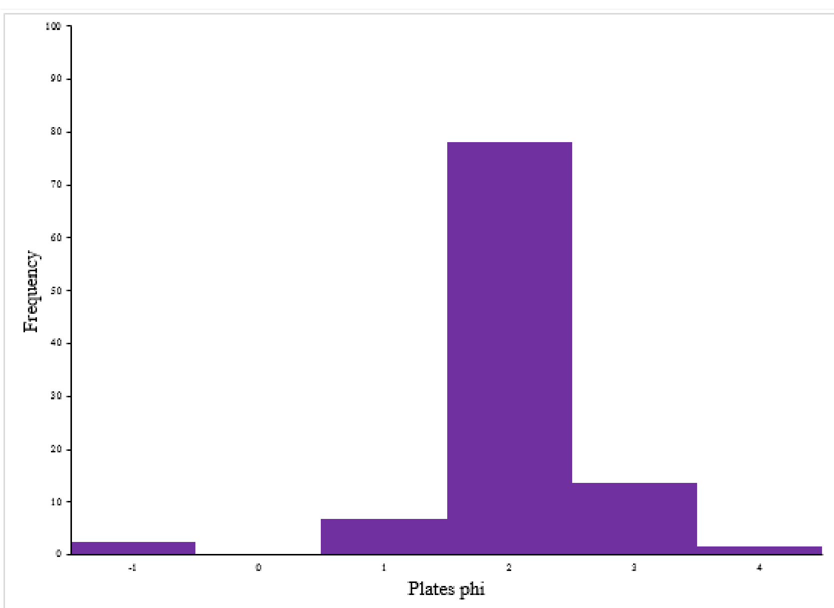

Figure D22. Frequency histogram of the particle grain size distribution for sample 1 from transect 4 in Cabo Rojo beach during sampling 1 (August/September 2016).

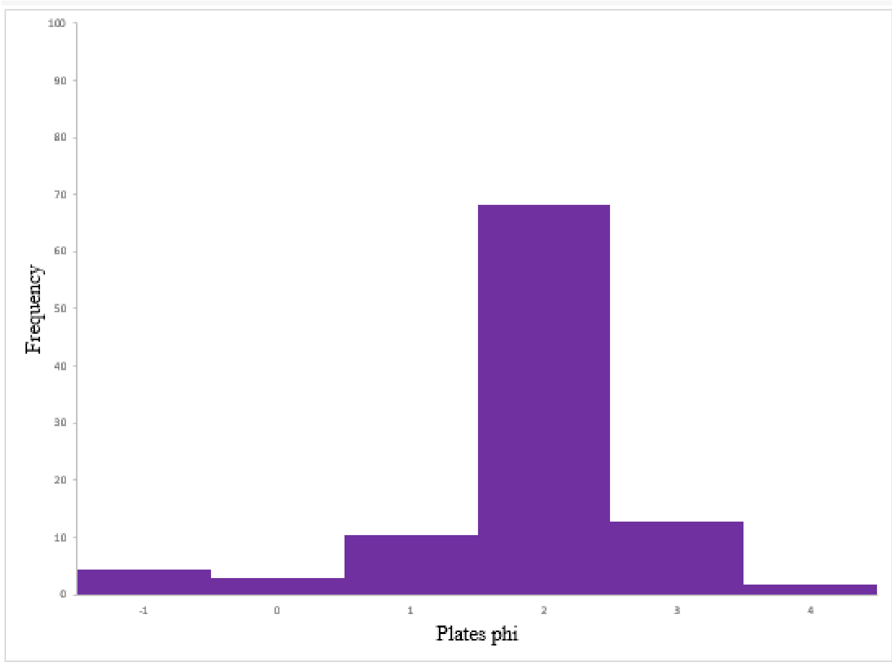

Figure D23. Frequency histogram of the particle grain size distribution for sample 2 from transect 4 in Cabo Rojo beach during sampling 1 (August/September 2016).

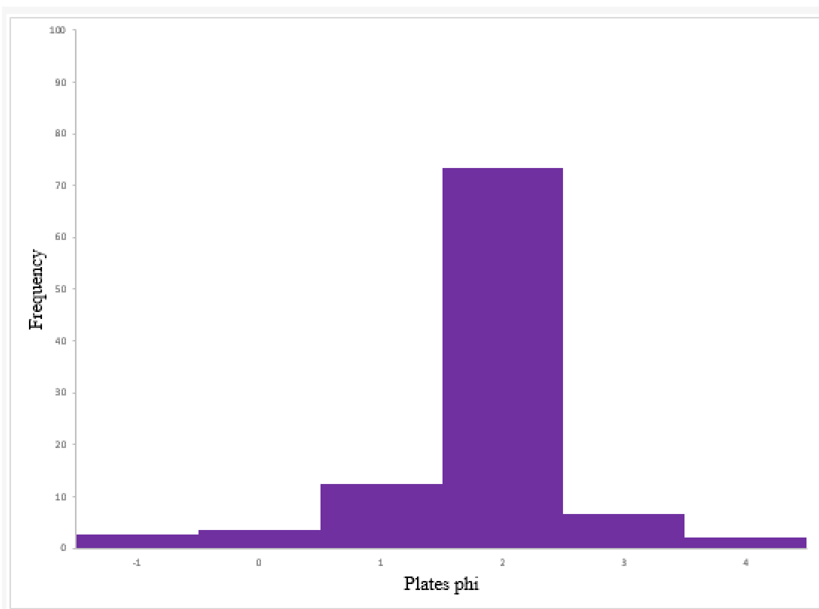

Figure D24. Frequency histogram of the particle grain size distribution for sample 3 from transect 4 in Cabo Rojo beach during sampling 1 (August/September 2016).

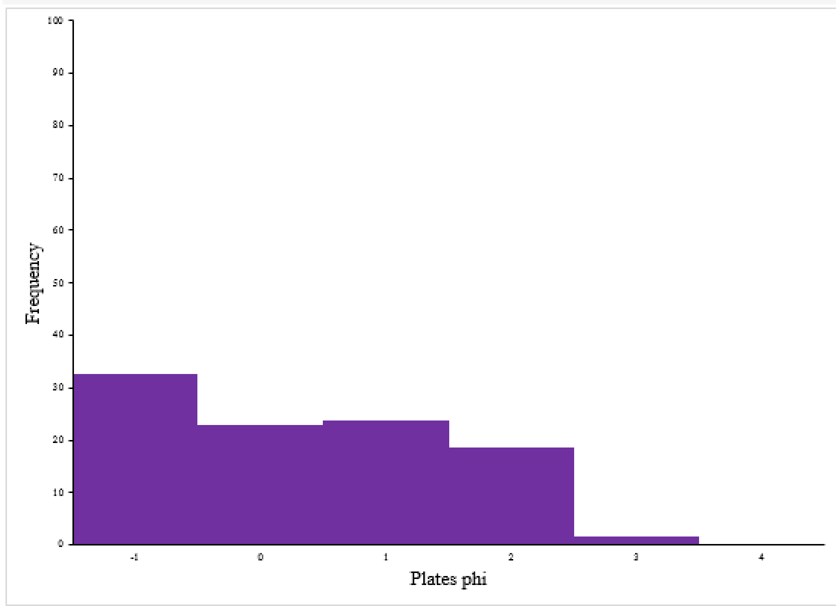

Figure D25. Frequency histogram of the particle grain size distribution for sample 4 from transect 4 in Cabo Rojo beach during sampling 1 (August/September 2016).

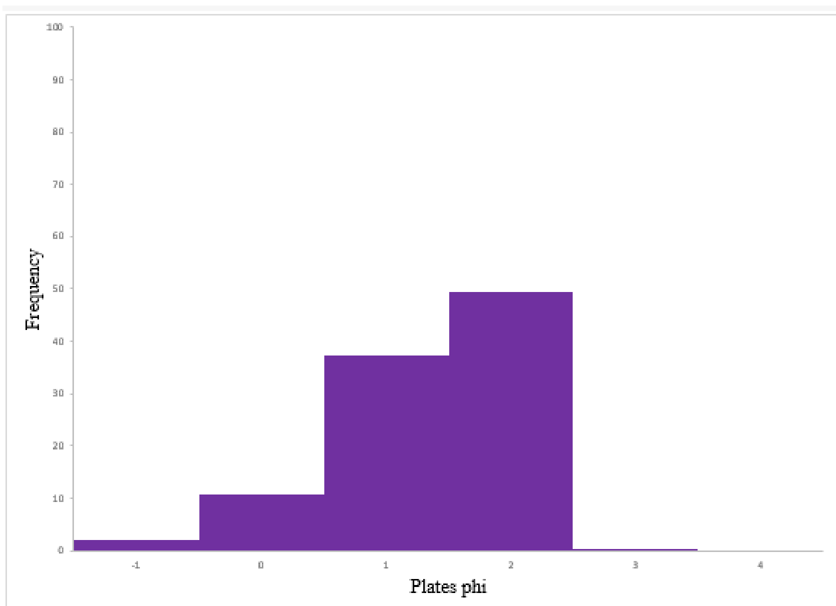

Figure D26. Frequency histogram of the particle grain size distribution for sample 5 from transect 4 in Cabo Rojo beach during sampling 1 (August/September 2016).

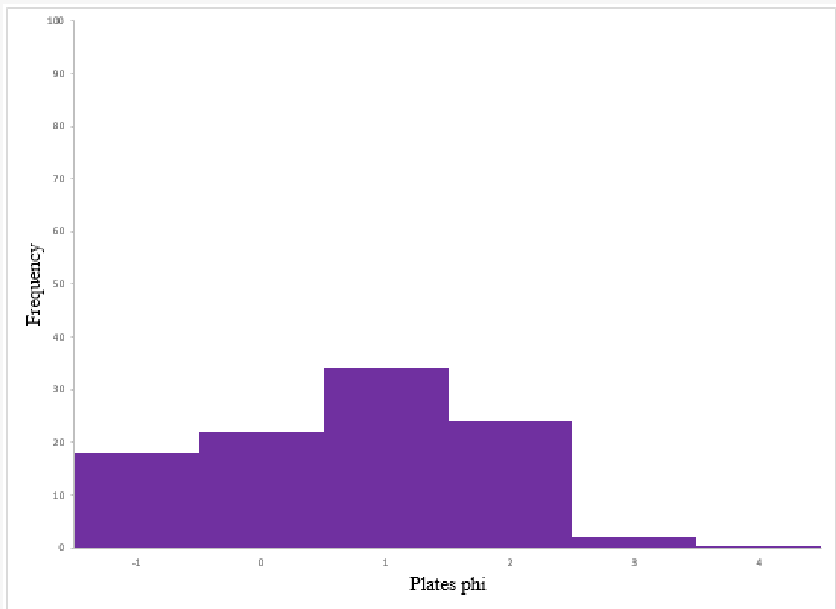

Figure D27. Frequency histogram of the particle grain size distribution for sample 6 from transect 4 in Cabo Rojo beach during sampling 1 (August/September 2016).

Table D28. Granulometry calculation for histograms of Transect 4 with all samples (1,2,3,4,5,6) at Cabo Rojo in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 4			
Sample 1	-1	2.4	2.5
	0	1.5	0.01
	1	6.5	6.7
	2	75.7	78.1
	3	13.2	13.6
	4	1.5	1.5
	Total	96.9	
Sample 2	-1	4.2	4.19
	0	3	7.19
	1	10.5	17.67
	2	68.2	85.80
	3	12.6	98.38

	4	1.6	99.98
	Total	100.1	
Sample 3	-1	2.6	2.56
	0	3.4	5.92
	1	12.5	18.25
	2	74.2	91.49
	3	6.6	98.00
	4	2	99.98
	Total	101.3	
Sample 4	-1	33.1	32.8
	0	23.1	22.9
	1	24.1	23.9
	2	18.8	18.6
	3	1.7	1.7
	4	0.2	0.2
	Total	101	
Sample 5	-1	2.1	2.07
	0	10.8	12.76
	1	37.7	50.08
	2	50	99.58
	3	0.4	99.98
	4	0	99.98
	Total	101	
Sample 6	-1	19.1	17.81
	0	23.5	39.73
	1	36.6	73.87
	2	25.6	97.75
	3	2.2	99.80
	4	0.2	99.98
	Total	107.2	

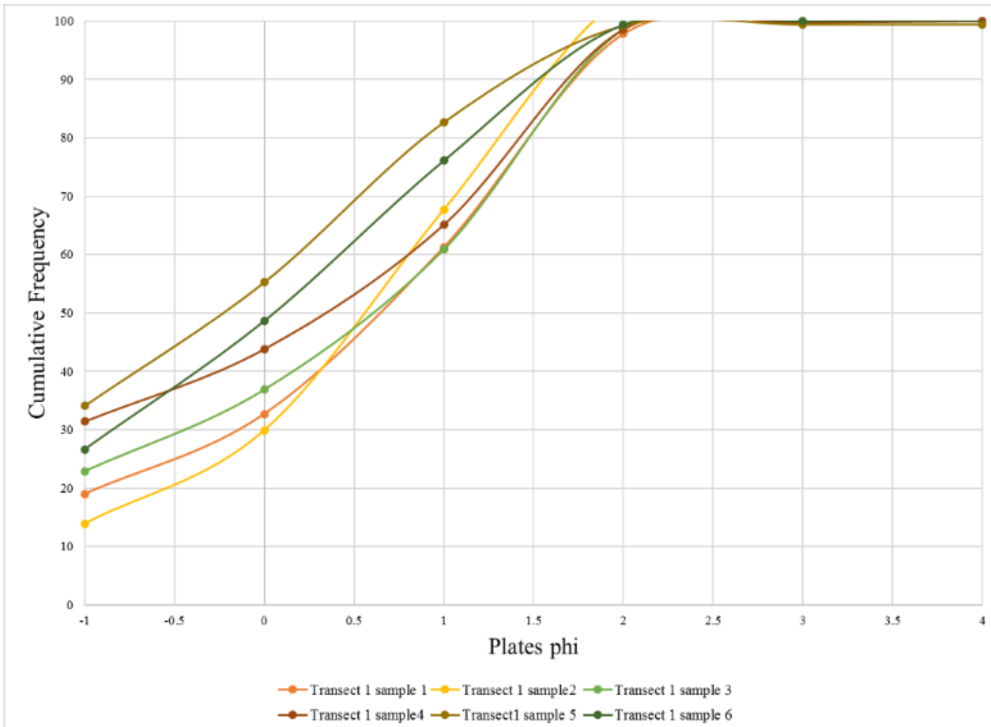

Figure D29. Cumulative frequency of the particle grain size distribution with samples 1-6 in Transect 1 at Cabo Rojo in sampling 1 (August/September 2016).

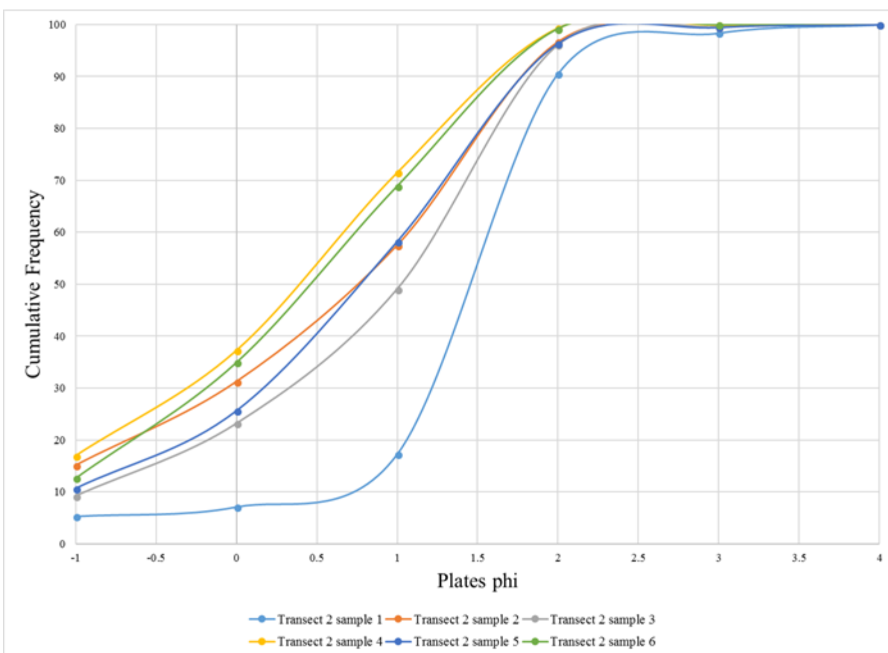

Figure D30. Cumulative frequency of the particle grain size distribution with samples 1-6 in Transect 2 at Cabo Rojo in sampling 1 (August/September 2016).

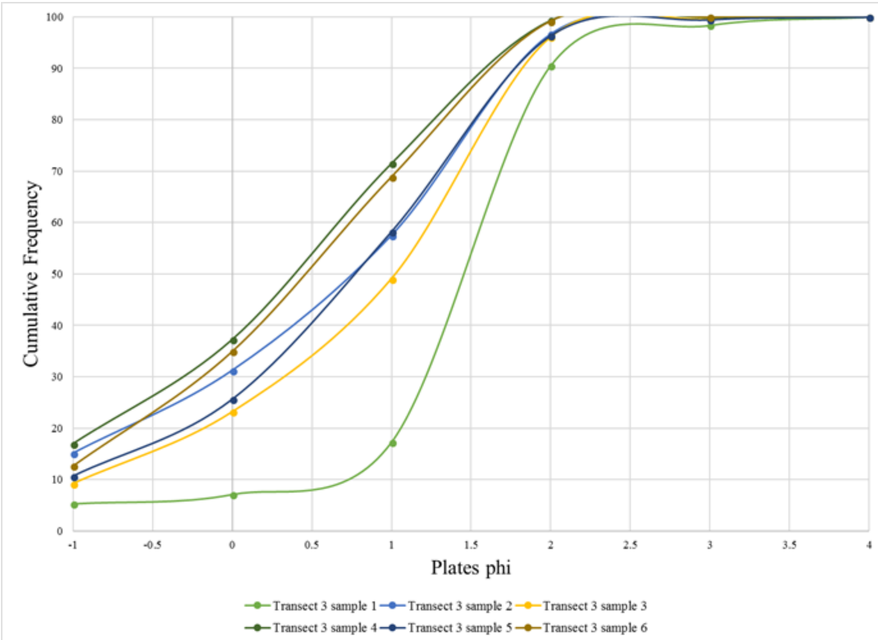

Figure D31. Cumulative frequency of the particle grain size distribution with samples 1-6 in Transect 3 at Cabo Rojo in sampling 1 (August/September 2016).

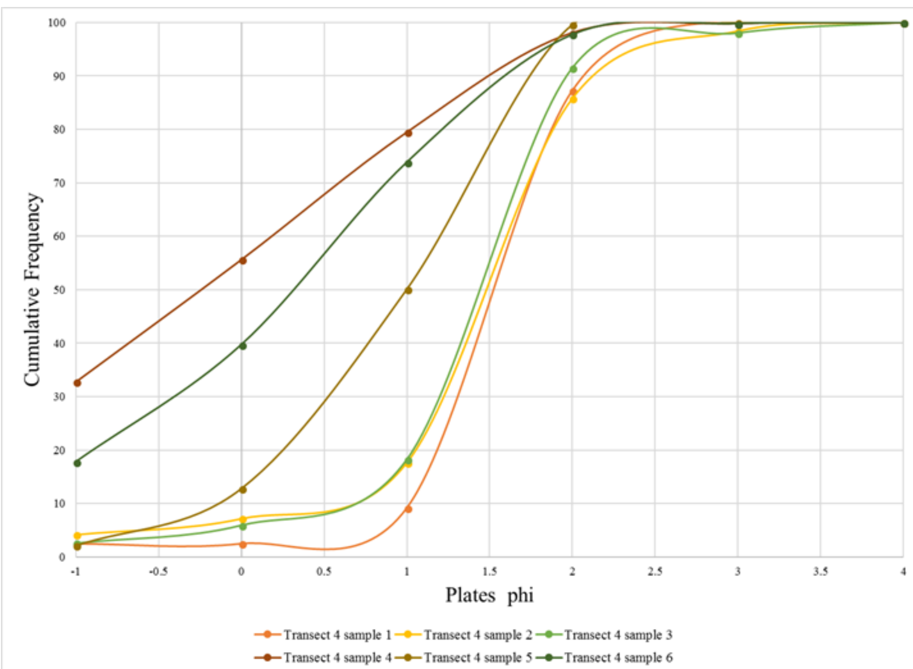

Figure D32. Cumulative frequency of the particle grain size distribution with samples 1-6 in Transect 4 at Cabo Rojo in sampling 1 (August/September 2016).

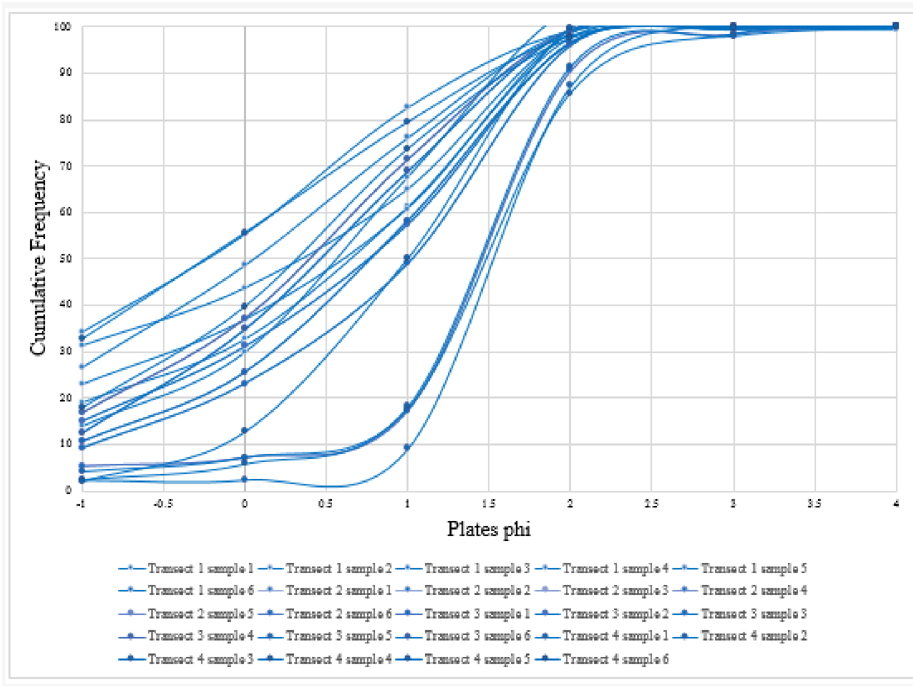

Figure D33. Cumulative frequency of the particle grain size distribution of all transects (T1, T2, T3, T4) and all samples (1,2,3,4,5,6) in sampling 1 (August/September 2016).

Table D34. Granulometry calculation of cumulative frequency and histograms of the particle grain size distribution for all transects (T1, T2, T3, T4) and all samples (1,2,3,4,5,6) in Cabo Rojo beach at sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency	Frequency
Transect 1			Cumulative curve	Histograms
Sample 1	-1	19.8	18.9	18.9
	0	14.3	32.7	13.7
	1	29.8	61.3	28.6
	2	38.1	97.8	36.5
	3	2	99.7	1.9
	4	0.4	100	0.4
	Total	104.3		
Sample 2	-1	15.1	13.94	13.94
	0	17.3	29.91	15.97
	1	25.1	67.67	37.76
	2	47.3	104.05	36.38

	3	2.9	106.72	2.67
	4	0.6	107.27	0.554
	Total	108.3		
Sample 3	-1	23.9	22.87	22.87
	0	14.6	36.84	13.97
	1	25.1	60.85	24.01
	2	39.4	98.55	37.7
	3	1.3	99.79	1.24
	4	0.4	100.172	0.382
	Total	104.5		
Sample 4	-1	37	31.4	31.4
	0	14.6	43.8	12.4
	1	25.1	65.1	21.3
	2	39.4	98.5	33.4
	3	1.3	99.6	1.1
	4	0.4	99.9	0.3
	Total	117.8		
Sample 5	-1	35	34.11	34.11
	0	21.7	55.26	21.15
	1	28.1	82.64	27.38
	2	17	99.2	16.56
	3	0.2	99.394	0.194
	4	0	99.394	0
	Total	102.6		
Sample 6	-1	26.2	26.65	26.65
	0	21.6	48.62	21.97
	1	27	76.08	27.46
	2	22.9	99.37	23.29
	3	0.6	99.98	0.61
	4	0	100.078	0.098
	Total	98.3		

Transect 2				
Sample 1	-1	5.3	5.326	5.3
	0	1.8	7.135	1.8
	1	10.1	17.285	10.1
	2	72.9	90.545	73.3
	3	7.8	98.384	5.8
	4	1.6	99.992	1.6
	Total	99.5		
Sample 2	-1	15	15.1	15.1
	0	16	31.21	16.11
	1	26.1	57.49	26.28
	2	38.9	96.66	39.17
	3	2.8	99.479	2.819
	4	0.5	99.982	0.503
	Total	99.3		
Sample 3	-1	9	9.183	9.183
	0	13.7	23.153	13.97
	1	25.4	49.063	25.91
	2	46.1	96.103	47.04
	3	3.4	99.572	3.469
	4	0.4	99.98	0.408
	Total	98		
Sample 4	-1	21.4	16.9	21.1
	0	22.7	37.2	22.4
	1	37.4	71.5	36.8
	2	19.2	99.4	18.9
	3	0.7	99.9	0.7
	4	0.1	100.3	0.1
	Total	101.5		
Sample 5	-1	10.6	10.64	10.64
	0	14.9	25.59	14.95

	1	32.5	58.22	32.63
	2	38	96.37	38.15
	3	3.1	99.482	3.112
	4	0.5	99.984	0.502
	Total	99.6		
Sample 6	-1	12.8	12.67	12.67
	0	22.5	34.94	22.27
	1	34.3	68.9	33.96
	2	30.6	99.19	30.29
	3	0.8	99.982	0.792
	4	0	100.287	0.305
	Total	101		
Transect 3				
Sample 1	-1	5.3	5.3	5.3
	0	1.8	7.1	1.8
	1	10.1	17.3	10.1
	2	72.9	90.5	73.3
	3	7.8	98.4	7.8
	4	1.6	99.9	1.6
	Total	99.5		
Sample 2	-1	15	15.1	15.1
	0	16	31.21	16.11
	1	26.1	57.49	26.28
	2	38.9	96.66	39.17
	3	2.8	99.479	2.819
	4	0.5	99.982	0.503
	Total	99.3		
Sample 3	-1	9	9.183	9.183
	0	13.7	23.153	13.97
	1	25.4	49.063	25.91
	2	46.1	96.103	47.04

	3	3.4	99.572	3.469
	4	0.4	99.98	0.408
	Total	98		
Sample 4	-1	16.6	16.9	16.9
	0	19.9	37.2	20.3
	1	33.6	71.5	34.3
	2	27.3	99.4	27.8
	3	0.6	99.9	0.6
	4	0	100.3	0
	Total	98		
Sample 5	-1	10.6	10.64	10.64
	0	14.9	25.59	14.95
	1	32.5	58.22	32.63
	2	38	96.37	38.15
	3	3.1	99.482	3.112
	4	0.5	99.984	0.502
	Total	99.6		
Sample 6	-1	12.8	12.67	12.67
	0	22.5	34.94	22.27
	1	34.3	68.9	33.96
	2	30.6	99.19	30.29
	3	0.8	99.982	0.792
	4	0	100.287	0.305
	Total	101		
Transect 4				
Sample 1	-1	2.4	2.5	2.5
	0	1.5	2.5	0.0
	1	6.5	9.2	6.7
	2	75.7	87.3	78.1
	3	13.2	100.9	13.6
	4	1.5	102.5	1.5
	Total	96.9		
Sample 2	-1	4.2	4.195	4.195

	0	3	7.192	2.997
	1	10.5	17.672	10.48
	2	68.2	85.802	68.13
	3	12.6	98.382	12.58
	4	1.6	99.98	1.598
	Total	100.1		
Sample 3	-1	2.6	2.566	2.566
	0	3.4	5.922	3.356
	1	12.5	18.252	12.33
	2	74.2	91.492	73.24
	3	6.6	98.007	6.515
	4	2	99.981	1.974
	Total	101.3		
Sample 4	-1	33.1	32.8	32.8
	0	23.1	55.6	22.9
	1	24.1	79.5	23.9
	2	18.8	98.1	18.6
	3	1.7	99.8	1.7
	4	0.2	99.9	0.2
	Total	101		
Sample 5	-1	2.1	2.079	2.079
	0	10.8	12.769	10.69
	1	37.7	50.089	37.32
	2	50	99.589	49.5
	3	0.4	99.985	0.396
	4	0	99.985	0
	Total	101		
Sample 6	-1	19.1	17.81	17.81
	0	23.5	39.73	21.92
	1	36.6	73.87	34.14
	2	25.6	97.75	23.88

	3	2.2	99.802	2.052
	4	0.2	99.988	0.186
	Total	107.2		

Appendix E

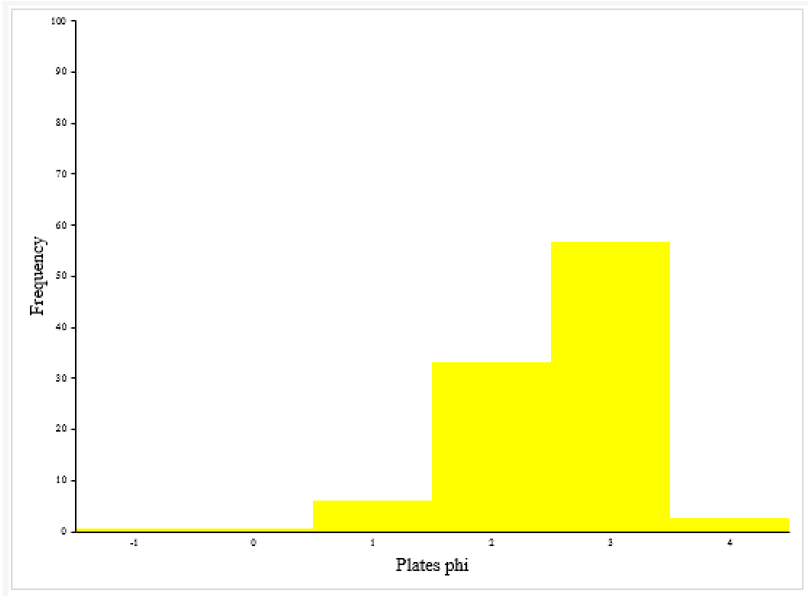

Figure E1. Frequency histogram of the particle grain size distribution for sample 1 from transect 1 in Mayagüez beach during sampling 1 (August/September 2016).

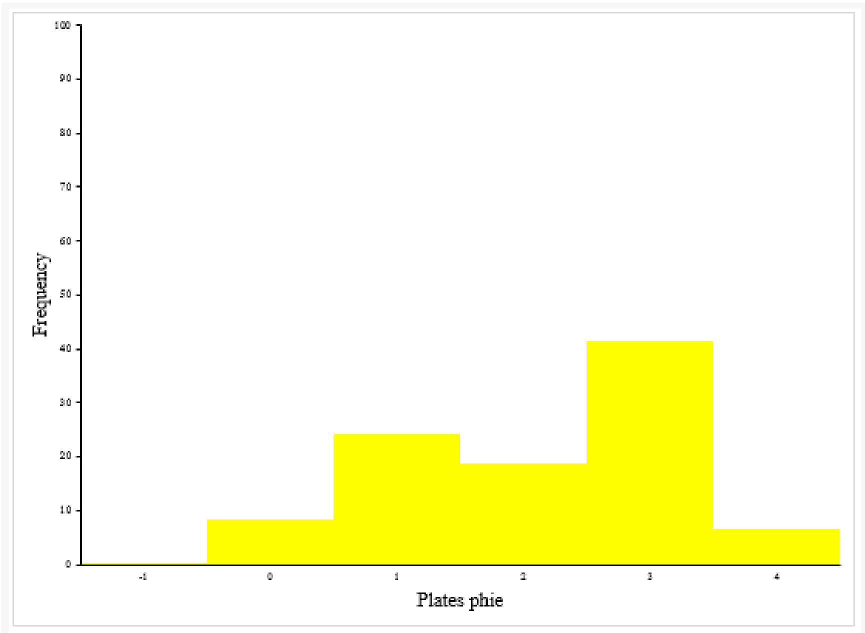

Figure E2. Frequency histogram of the particle grain size distribution for sample 4 from transect 1 in Mayagüez beach during sampling 1 (August/September 2016).

Table E3. Granulometry calculation of histograms for Transect 1, samples 1 and 4, at Mayagüez in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 1			
Sample 1	-1	0.7	0.7
	0	0.6	0.6
	1	6	6.0
	2	33	33.3
	3	56.3	56.7
	4	2.6	2.6
	Total	99.2	
Sample 4	-1	0.3	0.3
	0	8.3	8.4
	1	23.8	24.2
	2	18.4	18.7
	3	40.8	41.5
	4	6.6	6.7
	Total	98.2	

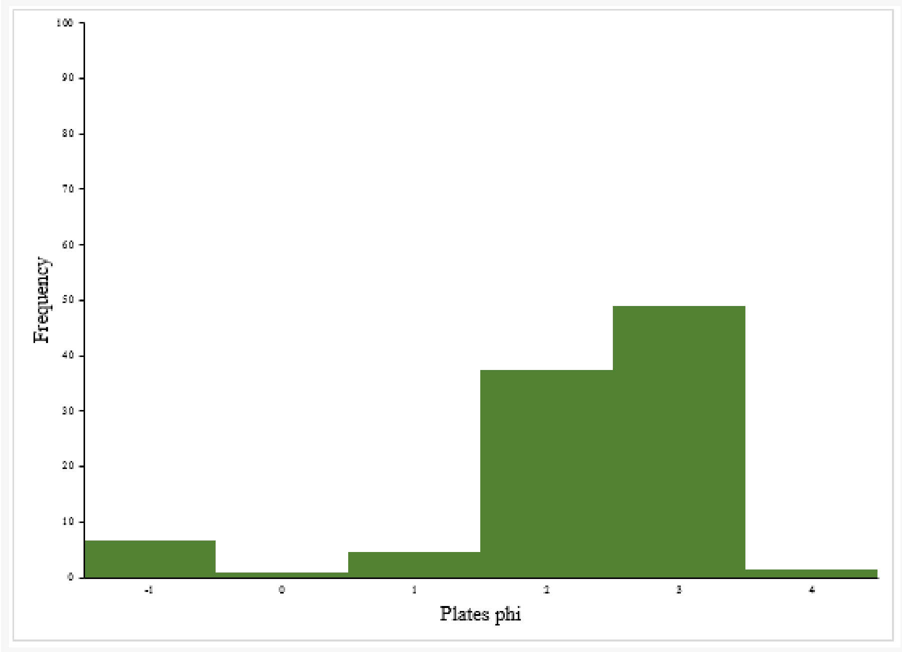

Figure E4. Frequency histogram of the particle grain size distribution for sample 1 from transect 2 in Mayagüez beach during sampling 1 (August/September 2016).

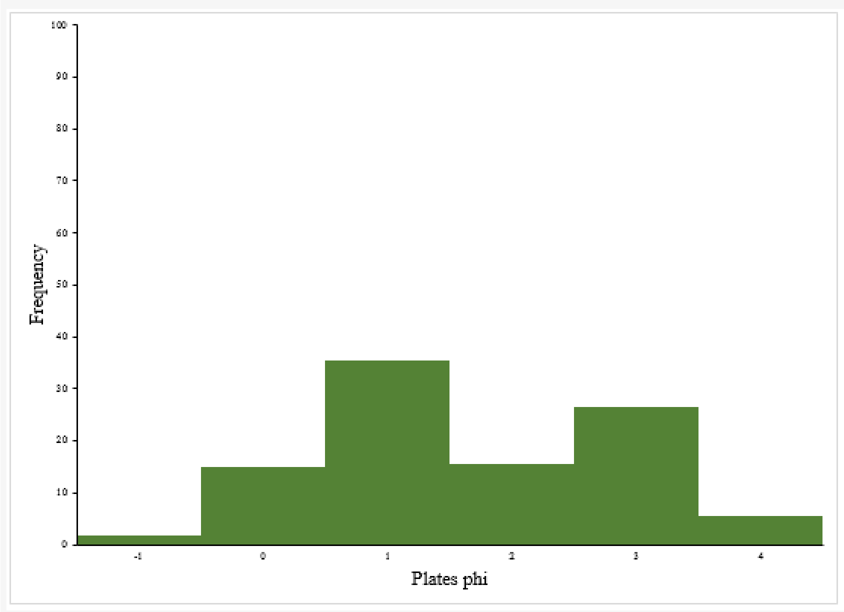

Figure E5. Frequency histogram of the particle grain size distribution for sample 4 from transect 2 in Mayagüez beach during sampling 1 (August/September 2016).

Table E6. Granulometry calculation of histograms for Transect 2, samples 1 and 4 at Mayagüez in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 2			
Sample 1	-1	7	6.6
	0	0.9	0.8
	1	4.9	4.6
	2	39.5	37.3
	3	51.8	48.9
	4	1.7	1.6
	Total	105.8	
Sample 4	-1	1.7	1.7
	0	15.1	15.1
	1	35.4	35.4
	2	15.7	15.7
	3	26.5	26.5
	4	5.6	5.6
	Total	100	

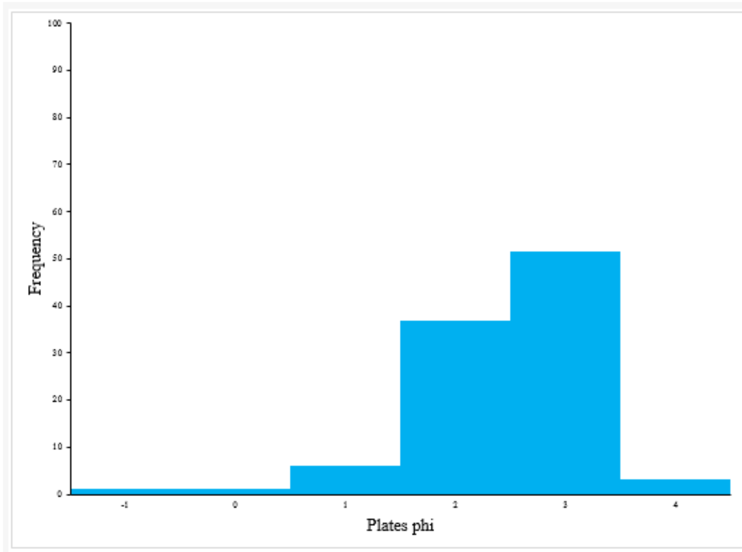

Figure E7. Frequency histogram of the particle grain size distribution for sample 1 from transect 3 in Mayagüez beach during sampling 1 (August/September 2016).

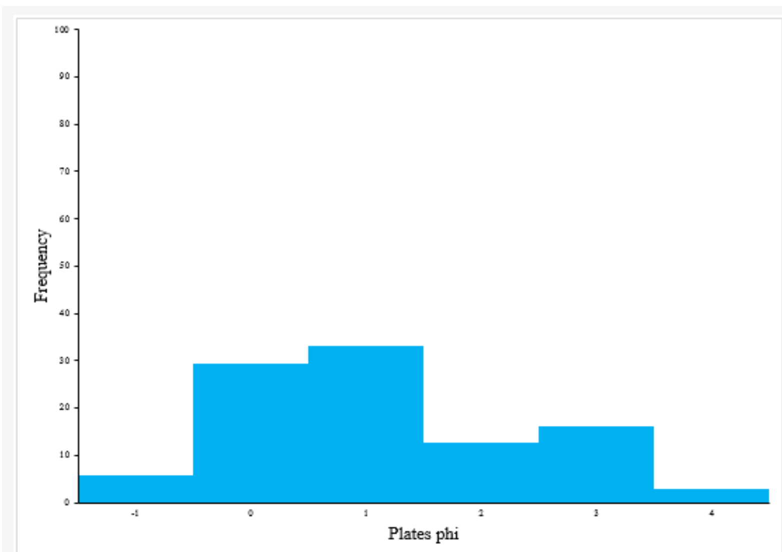

Figure E8. Frequency histogram of the particle grain size distribution for sample 4 from transect 3 in Mayagüez beach during sampling 1 (August/September 2016).

Table E9. Granulometry calculation of histograms for Transect 3, samples 1 and 4, at Mayagüez in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 3			
Sample 1	-1	1.2	1.2
	0	1.1	1.1
	1	6.1	6.1
	2	37	36.8
	3	51.9	51.6
	4	3.3	3.3
	Total	100.6	
Sample 4	-1	5.9	5.8
	0	29.5	29.3
	1	33.3	33.0
	2	12.9	12.8
	3	16.4	16.3
	4	2.8	2.8
	Total	100.8	

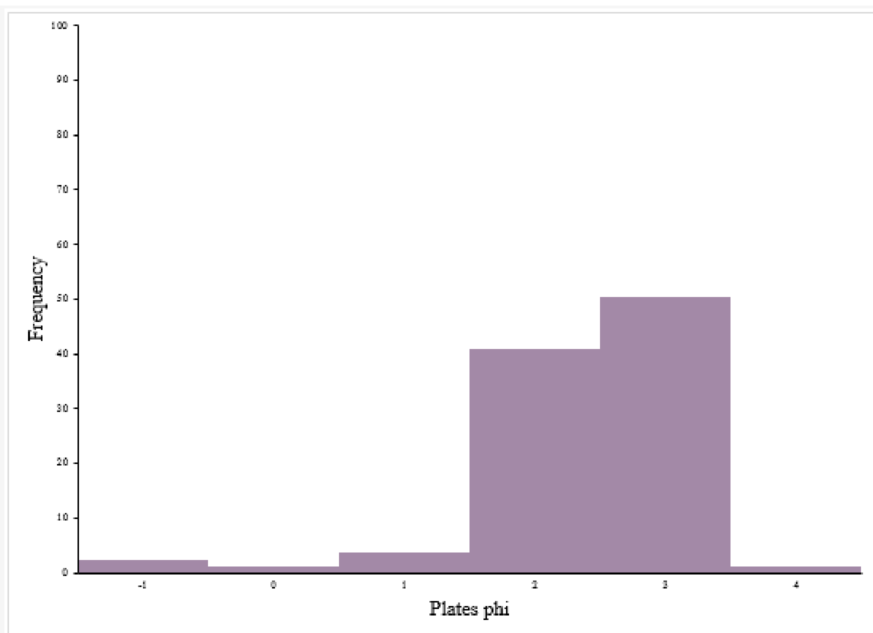

Figure E10. Frequency histogram of the particle grain size distribution for sample 1 from transect 4 in Mayagüez beach during sampling 1 (August/September 2016).

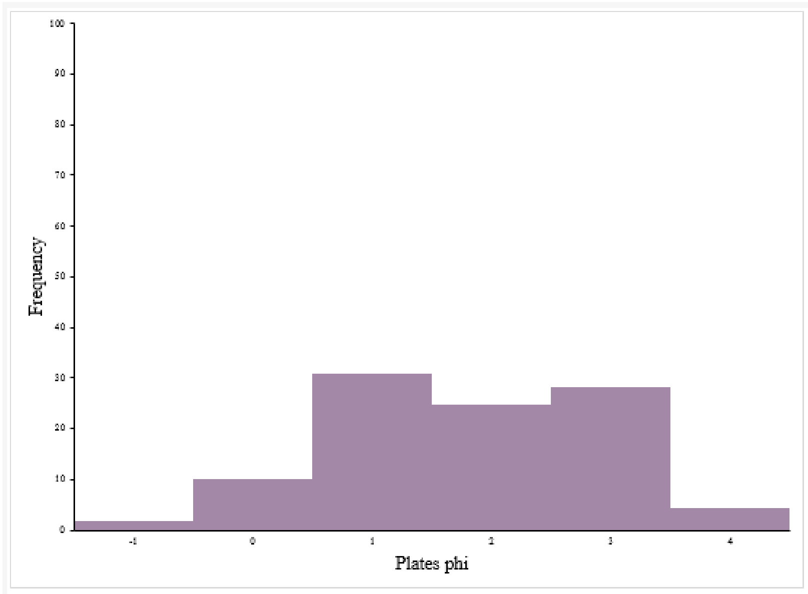

Figure E11. Frequency histogram of the particle grain size distribution for sample 4 from transect 4 in Mayagüez beach during sampling 1 (August/September 2016).

Table E12. Granulometry calculation of histograms for Transect 4, samples 1 and 4, at Mayagüez in sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 4			
Sample 1	-1	2.4	2.4
	0	1.2	1.1
	1	3.9	3.8
	2	41.5	40.9
	3	51	50.3
	4	1.3	1.3
	Total	101.3	
Sample 4	-1	1.8	1.8
	0	9.9	9.9
	1	30.6	30.9
	2	24.5	24.7
	3	28.1	28.3
	4	4.2	4.2
	Total	99.1	

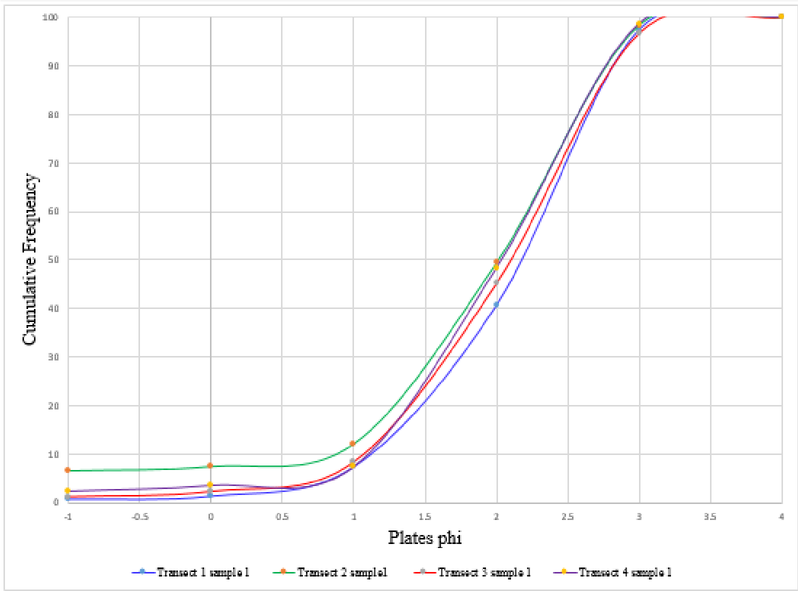

Figure E13. Cumulative Frequency of sample 1 in all transects (T1, T2, T3, T4) at Mayagüez in Sampling 1 (August/September 2016).

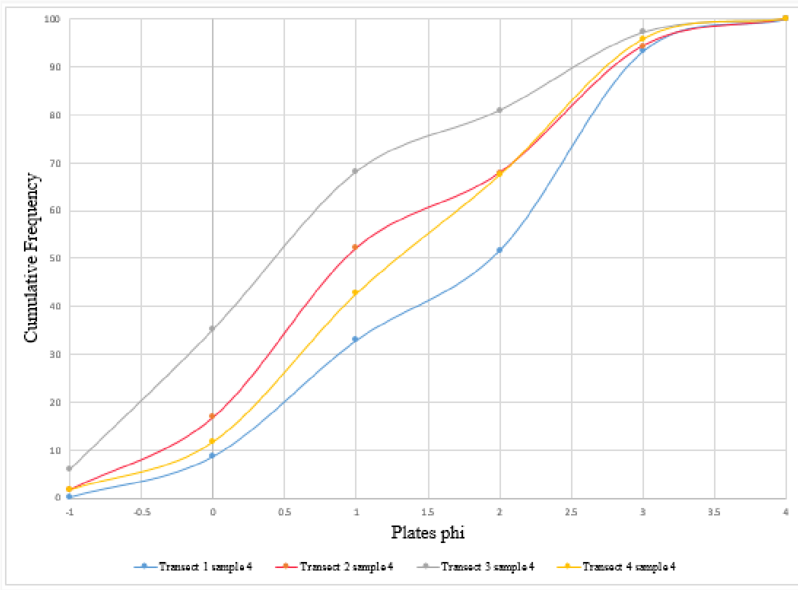

Figure E14. Cumulative frequency of the particle grain size distribution for sample 4 in all transects (T1, T2, T3, T4) at Mayagüez in sampling 1 (August/September 2016).

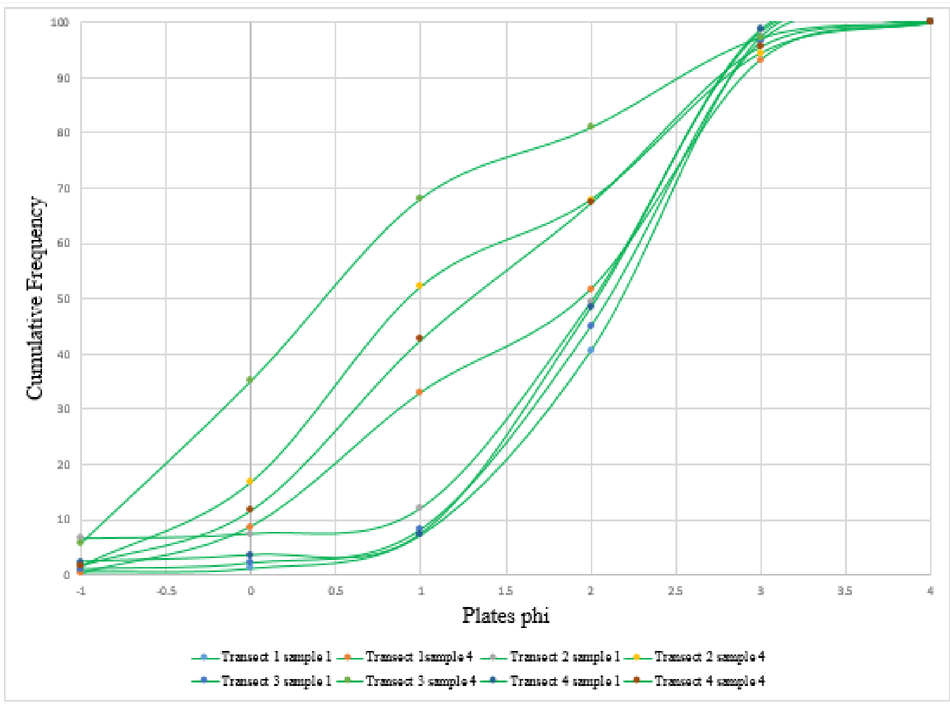

Figure E15. Cumulative frequency of the particle grain size distribution for all transects (T1, T2, T3, T4), samples 1 and 4, at Mayagüez in sampling 1 (August/September 2016).

Table E16. Granulometry calculation of cumulative frequency and histograms for transects (T1, T2, T3, T4) in samples (1 and 4) in Mayagüez beach at sampling 1 (August/September 2016).

Transect	Plates phi	Weight (grams)	Frequency	Frequency
Transect 1			Cumulative curve	Histograms
Sample 1	-1	0.7	0.7	0.7
	0	0.6	1.3	0.6
	1	6	7.3	6.0
	2	33	40.6	33.3
	3	56.3	97.4	56.7
	4	2.6	100	2.6
	Total	99.2		
Sample 4	-1	0.3	0.3	0.3
	0	8.3	8.7	8.4
	1	23.8	32.9	24.2
	2	18.4	51.7	18.7
	3	40.8	93.3	41.5
	4	6.6	100	6.7
	Total	98.2		

Transect 2				
Sample 1	-1	7	6.6	6.6
	0	0.9	7.5	0.8
	1	4.9	12.1	4.6
	2	39.5	49.4	37.3
	3	51.8	98.4	48.9
	4	1.7	100	1.6
	Total	105.8		
Sample 4	-1	1.7	1.7	1.7
	0	15.1	16.8	15.1
	1	35.4	52.2	35.4
	2	15.7	67.9	15.7
	3	26.5	94.4	26.5
	4	5.6	100	5.6
	Total	100		
Transect 3				
Sample 1	-1	1.2	1.2	1.2
	0	1.1	2.3	1.1
	1	6.1	8.3	6.1
	2	37	45.1	36.8
	3	51.9	96.7	51.6
	4	3.3	100	3.3
	Total	100.6		
Sample 4	-1	5.9	5.8	5.8
	0	29.5	35.1	29.3
	1	33.3	68.1	33.0
	2	12.9	80.9	12.8
	3	16.4	97.2	16.3
	4	2.8	100	2. 8
	Total	100.8		
Transect 4				
Sample 1	-1	2.4	2.4	2.4
	0	1.2	3.5	1.2
	1	3.9	7.4	3.8
	2	41.5	48.4	40.9
	3	51	98.7	50.3
	4	1.3	100	1.3
	Total	101.3		
Sample 4	-1	1.8	1.8	1.8
	0	9.9	11.8	9.9
	1	30.6	42.7	30.9
	2	24.5	67.4	24.7

	3	28.1	95.8	28.3
	4	4.2	100	4.2
	Total	99.1		

Appendix F

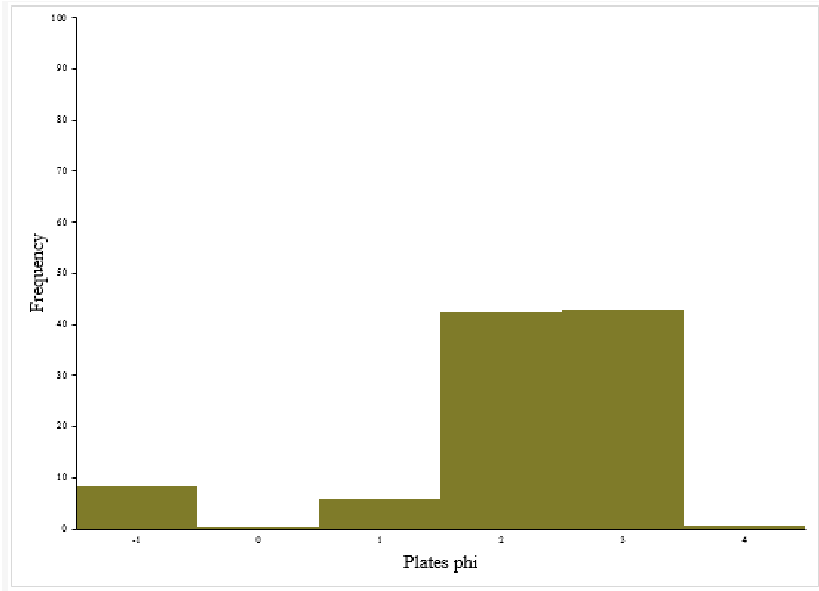

Figure F1. Frequency histogram of the particle grain size distribution for sample 1 from transect 1 in Añasco beach during sampling 2 (October/November 2016).

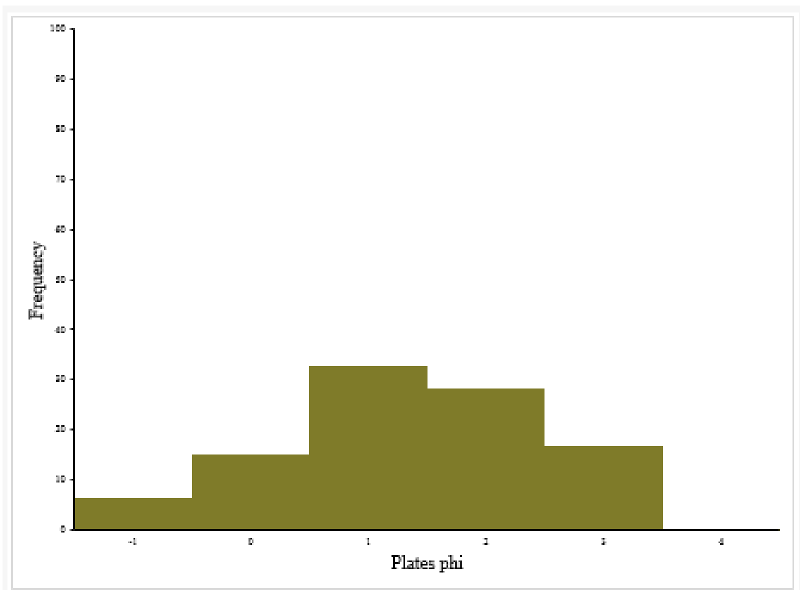

Figure F2. Frequency histogram of the particle grain size distribution for sample 4 from transect 1 in Añasco beach during sampling 2 (October/November 2016).

Table F3. Granulometry calculation of histograms of the particle grain size distribution for Transect 1, samples 1 and 4 at Añasco in sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 1			
Sample 1	-1	8.8	8.3
	0	0.3	0.3
	1	6	5.7
	2	44.5	42.3
	3	45.2	42.9
	4	0.5	0.3
	Total	105.3	
Sample 4	-1	6.7	6.5
	0	15.7	15.3
	1	33.6	32.7
	2	29	28.2
	3	17.4	16.9
	4	0.3	0.3
	Total	102.7	

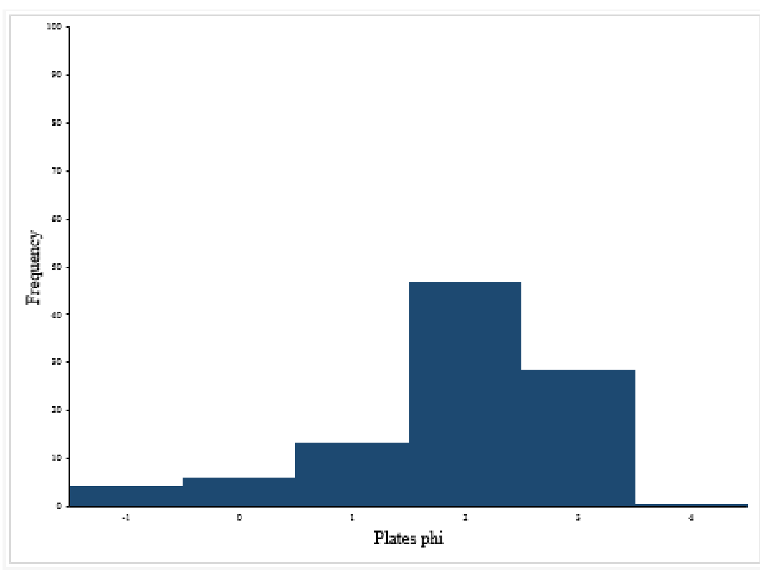

Figure F4. Frequency histogram of the particle grain size distribution for sample 1 from transect 2 in Añasco beach during sampling 2 (October/November 2016).

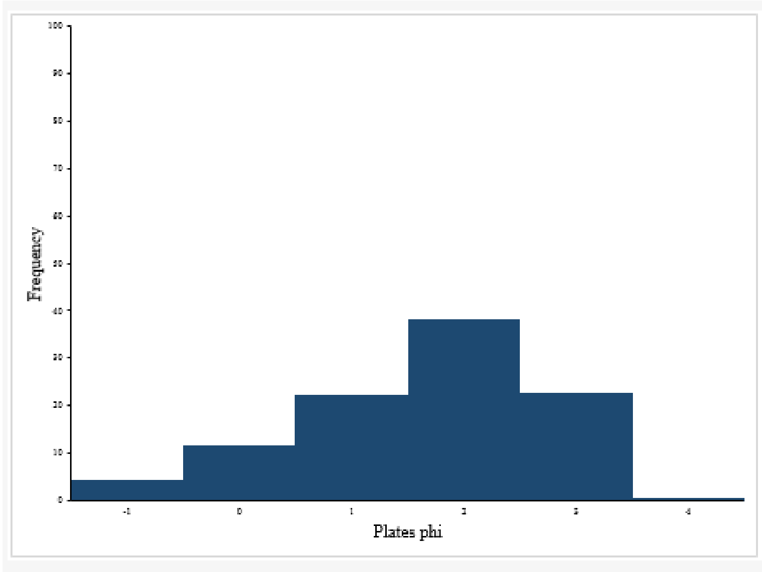

Figure F5. Frequency histogram of the particle grain size distribution for sample 4 from transect 2 in Añasco beach during sampling 2 (October/November 2016).

Table F6. Granulometry calculation of histograms for the particle grain size distribution for Transect 2, samples 1 and 4 at Añasco in sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 2			
Sample 1	-1	4.6	4.5
	0	6.3	6.1
	1	13.5	13.2
	2	47.9	46.9
	3	29.3	28.7
	4	0.5	0.5
	Total	102.1	
Sample 4	-1	4.3	4.3
	0	11.5	11.5
	1	22.5	22.5
	2	38.2	38.3
	3	22.8	22.8
	4	0.5	0.5
	Total	99.8	

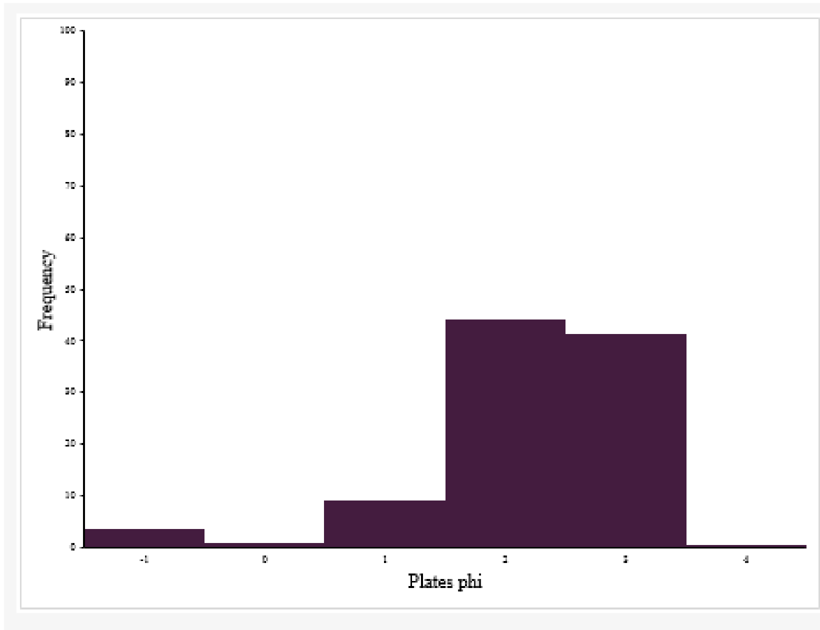

Figure F7. Frequency histogram of the particle grain size distribution for sample 1 from transect 3 in Añasco beach during sampling 2 (October/November 2016).

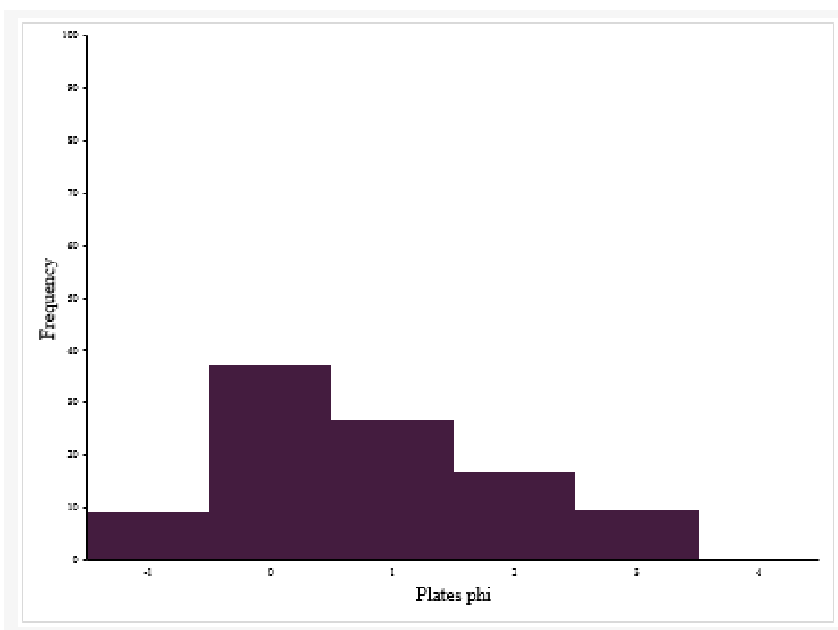

Figure F8. Frequency histogram of the particle grain size distribution for sample 4 from transect 3 in Añasco beach during sampling 2 (October/November 2016).

Table F9. Granulometry calculation of histograms for the particle grain size distribution for Transect 3, samples 1 and 4, at Añasco in sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 3			
Sample 1	-1	3.7	3.7
	0	0.9	0.9
	1	9.4	9.3
	2	44.5	44.1
	3	41.9	41.5
	4	0.5	0.5
	Total	100.9	
Sample 4	-1	9.4	9.3
	0	37.4	37.1
	1	27	26.8
	2	17.1	16.9
	3	9.8	9.7
	4	0	0
	Total	100.7	

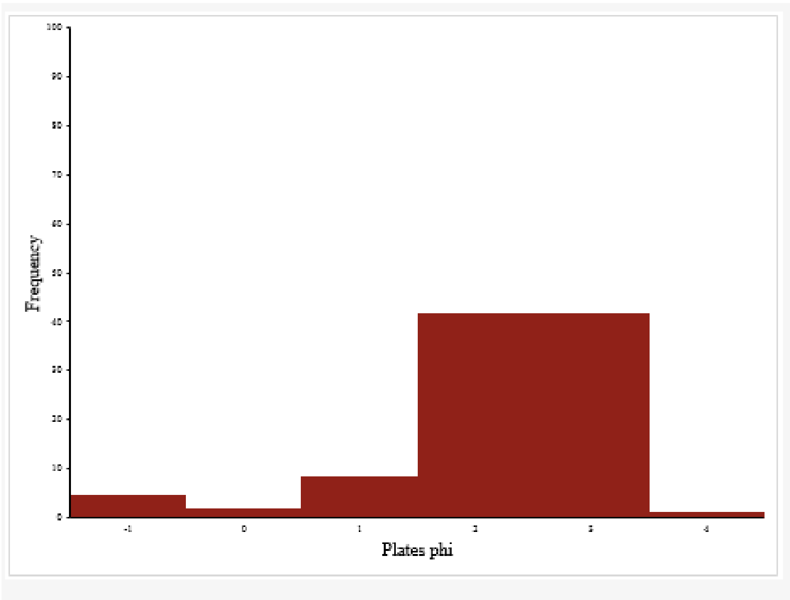

Figure F10. Frequency histogram of the particle grain size distribution for sample 1 from transect 4 in Añasco beach during sampling 2 (October/November 2016).

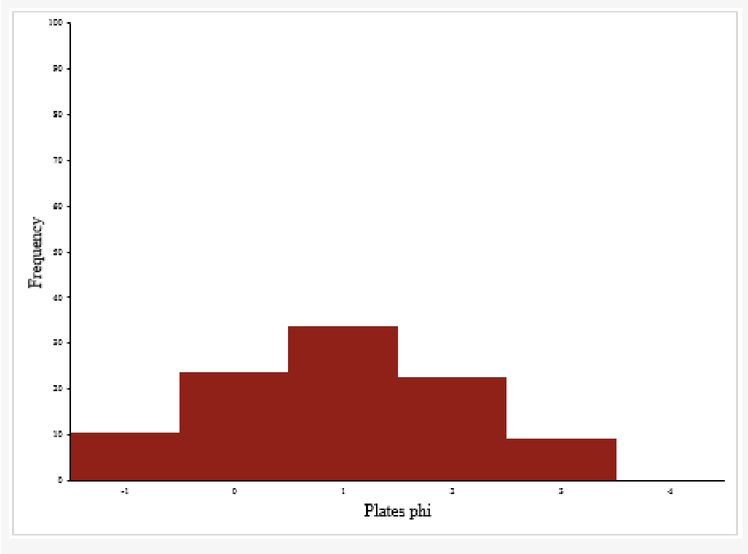

Figure F11. Frequency histogram of the particle grain size distribution for sample 4 from transect 4 in Añasco beach during sampling 2 (October/November 2016).

Table F12. Granulometry calculation of histograms for the particle grain size distribution for Transect 4, samples 1 and 4, at Añasco in sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 4			
Sample 1	-1	4.9	4.7
	0	2.1	2.0
	1	8.8	8.5
	2	43.2	41.7
	3	43.3	41.8
	4	1.3	1.2
	Total	103.6	
Sample 4	-1	10.8	10.5
	0	24.6	23.9
	1	34.7	33.7
	2	23.4	22.7
	3	9.4	9.1
	4	0.1	0.1
	Total	103	

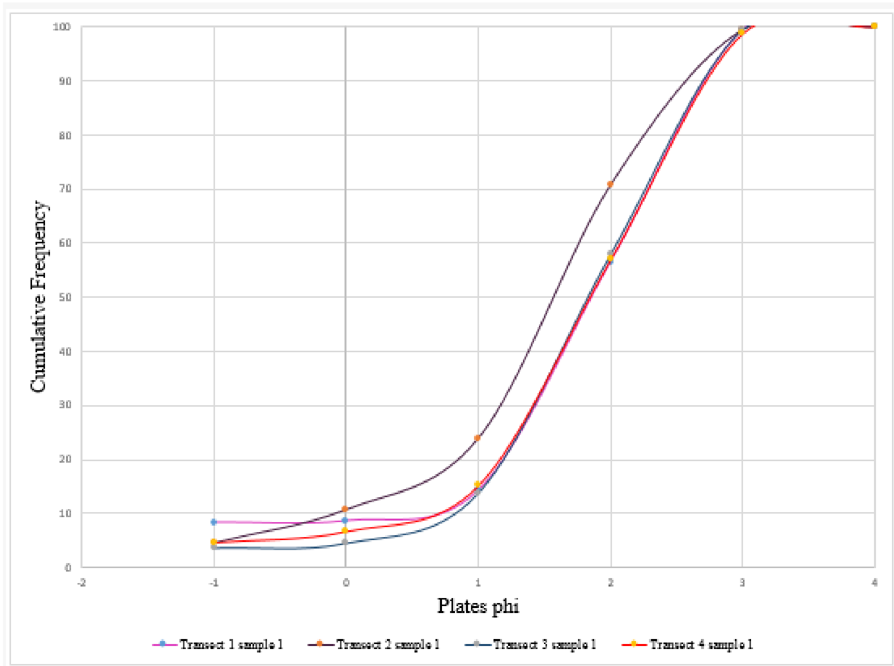

Figure F13. Cumulative frequency of the particle grain size distribution for sample 1 in all transects (T1, T2, T3, T4) at Añasco in sampling 2 (October/November 2016).

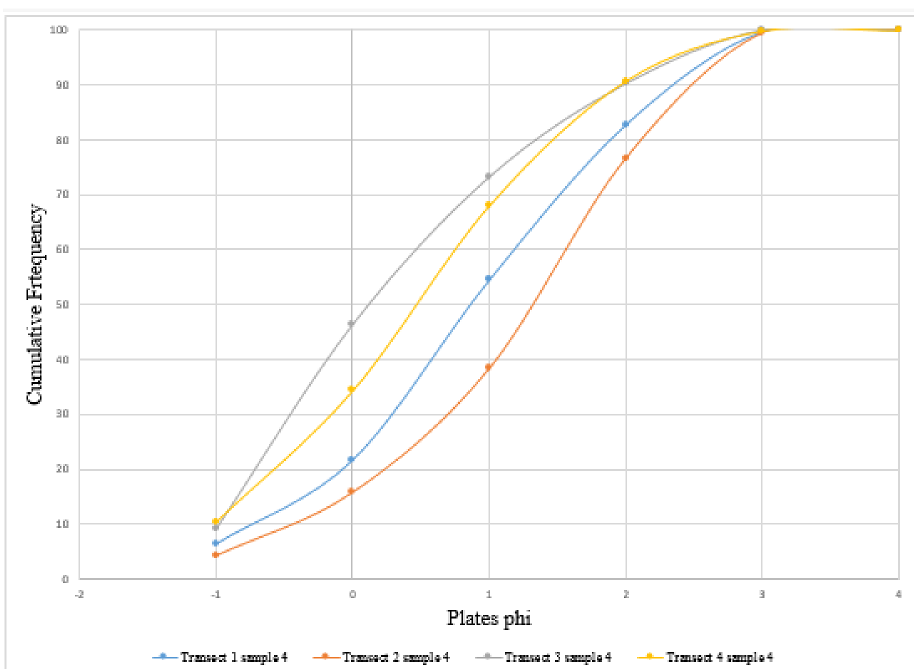

Figure F14. Cumulative frequency of the particle grain size distribution for sample 4 in all transects (T1, T2, T3, T4) at Añasco in sampling 2 (October/November 2016).

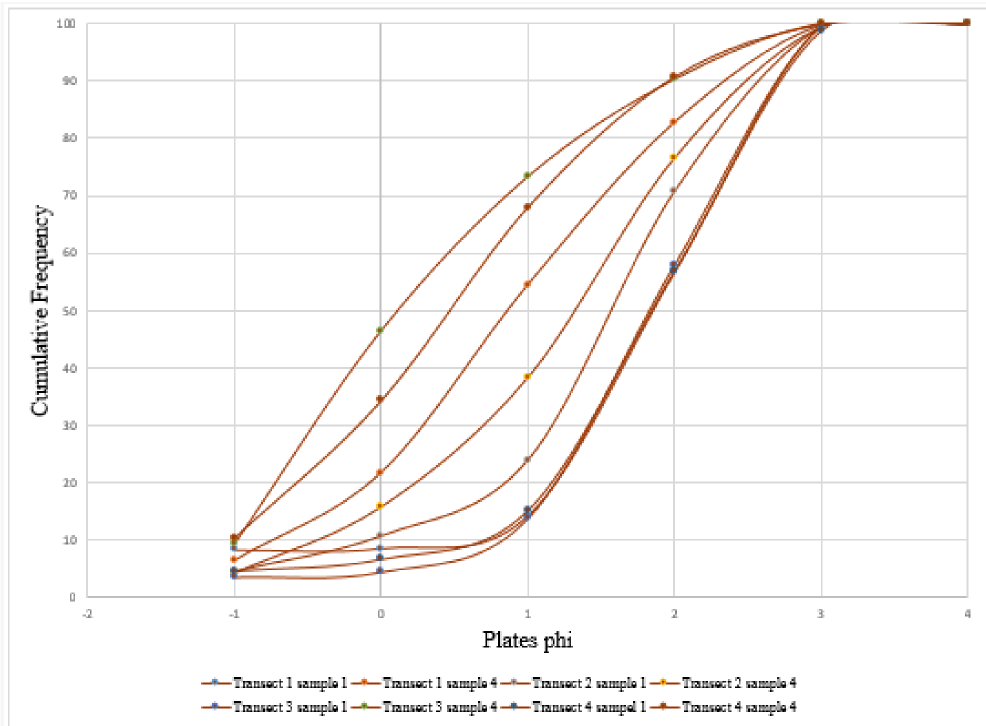

Figure F15. Cumulative frequency of the particle grain size distribution for all transects (T1, T2, T3, T4), samples 1 and 4, at Añasco in sampling 2 (October/November 2016).

Table F16. Granulometry calculation of cumulative frequency and histograms of the particle grain size distribution for all transects (T1, T2, T3, T4) and samples (1 and 4) in Añasco beach at sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency	Frequency
Transect 1			Cumulative curve	Histograms
Sample 1	-1	8.8	8.3	8.3
	0	0.3	8.6	0.3
	1	6	14.3	5.7
	2	44.5	56.6	42.3
	3	45.2	99.5	42.9
	4	0.5	100	0.5
	Total	105.3		
Sample 4	-1	6.7	6.5	6.5
	0	15.7	21.8	15.3
	1	33.6	54.5	32.7
	2	29	82.8	28.2
	3	17.4	99.7	16.9
	4	0.3	100	0.3

	Total	102.7		
Transect 2				
Sample 1	-1	4.6	4.5	4.5
	0	6.3	10.7	6.2
	1	13.5	23.9	13.2
	2	47.9	70.8	46.9
	3	29.3	99.5	28.7
	4	0.5	100	0.5
	Total	102.1		
Sample 4	-1	4.3	4.3	4.3
	0	11.5	15.8	11.5
	1	22.5	38.4	22.5
	2	38.2	76.6	38.3
	3	22.8	99.5	22.8
	4	0.5	100	0.5
	Total	99.8		
Transect 3				
Sample 1	-1	3.7	3.7	3.7
	0	0.9	4.5	0.9
	1	9.4	13.9	9.3
	2	44.5	57.9	44.1
	3	41.9	99.5	41.5
	4	0.5	100	0.5
	Total	100.9		
Sample 4	-1	9.4	9.3	9.3
	0	37.4	46.5	37.1
	1	27	73.3	26.8
	2	17.1	90.3	16.9
	3	9.8	100	9.7
	4	0	100	0
	Total	100.7		
Transect 4				
Sample 1	-1	4.9	4.7	4.7
	0	2.1	6.7	2.0
	1	8.8	15.2	8.5
	2	43.2	56.9	41.7
	3	43.3	98.7	41.8
	4	1.3	100	1.2
	Total	103.6		
Sample 4	-1	10.8	10.5	10.5
	0	24.6	34.4	23.9
	1	34.7	68.0	33.7

	2	23.4	90.8	22.7
	3	9.4	99.9	9.1
	4	0.1	100	0.1
	Total	103		

Appendix G

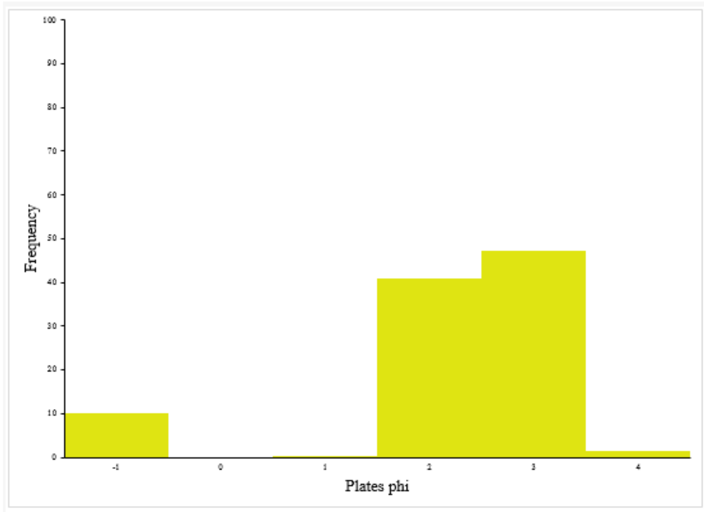

Figure G1. Frequency histogram of the particle grain size distribution for sample 1 from transect 1 in Cabo Rojo beach during sampling 2 (October/November 2016).

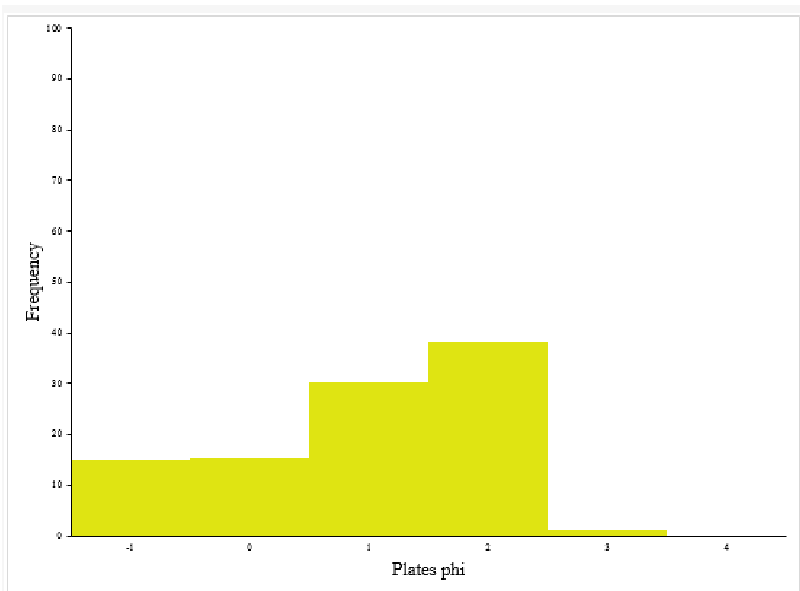

Figure G2. Frequency histogram of the particle grain size distribution for sample 4 from transect 1 in Cabo Rojo beach during sampling 2 (October/November 2016).

Table G3. Granulometry calculation of histograms for the particle grain size distribution for Transect 1, samples 1 and 4, at Cabo Rojo in sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 1			
Sample 1	-1	11.1	10.1

	0	0	0
	1	0.5	0.4
	2	45	40.9
	3	51.8	47.1
	4	1.5	1.4
	Total	109.9	
Sample 4	-1	15.7	14.9
	0	16.2	15.4
	1	31.9	30.3
	2	40.3	38.2
	3	1.3	1.2
	4	0	0
	Total	105.4	

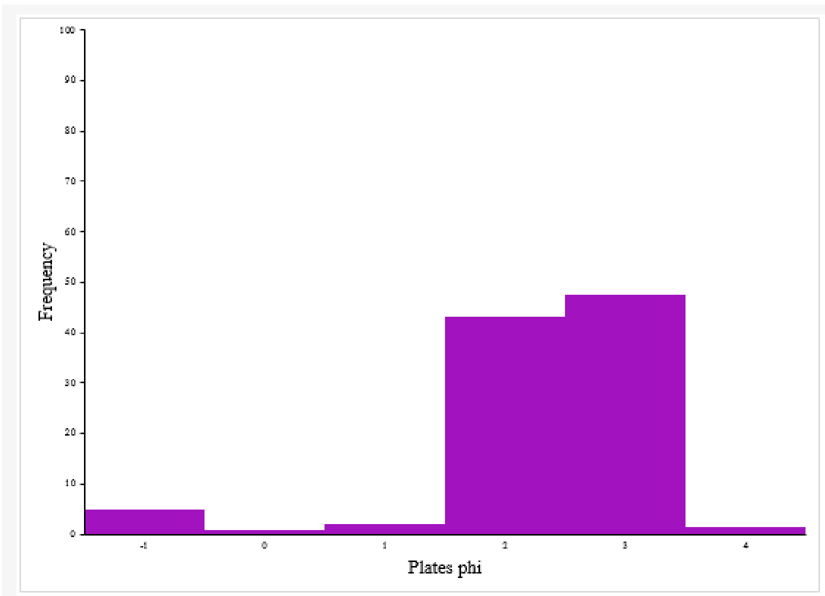

Figure G4. Frequency histogram of the particle grain size distribution for sample 1 from transect 2 in Cabo Rojo beach during sampling 2 (October/November 2016).

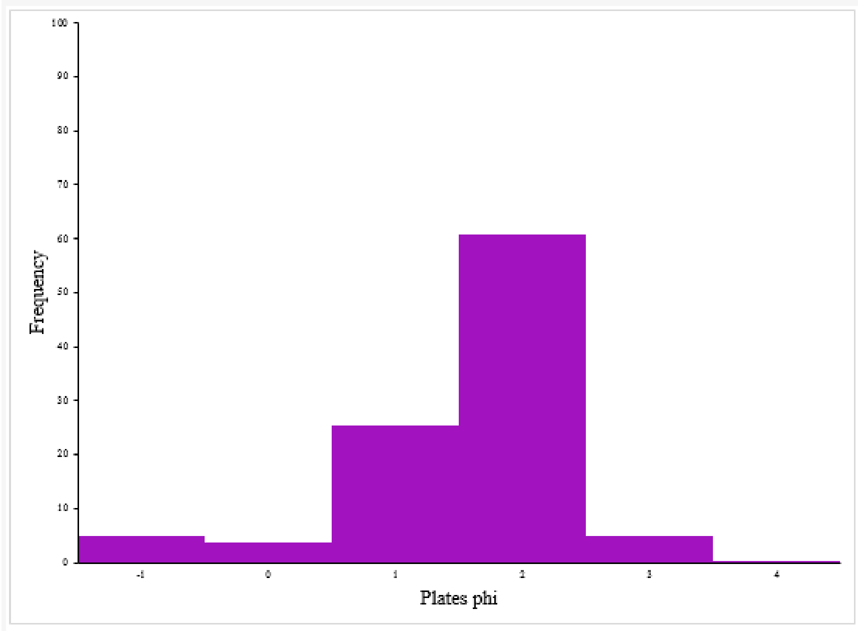

Figure G5. Frequency histogram of the particle grain size distribution for sample 4 from transect 2 in Cabo Rojo beach during sampling 2 (October/November 2016).

Table G6. Granulometry calculation of histograms for the particle grain size distribution for Transect 2, samples 1 and 4 at Cabo Rojo in sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 2			
Sample 1	-1	5.1	4.9
	0	0.9	0.9
	1	2.2	2.1
	2	44.5	43.2
	3	49.2	47.5
	4	1.4	1.3
	Total	103.5	
Sample 4	-1	5.1	4.9
	0	4	3.9
	1	26.3	25.5
	2	62.6	60.6
	3	5.1	4.9
	4	0.1	0.1
	Total	103.2	

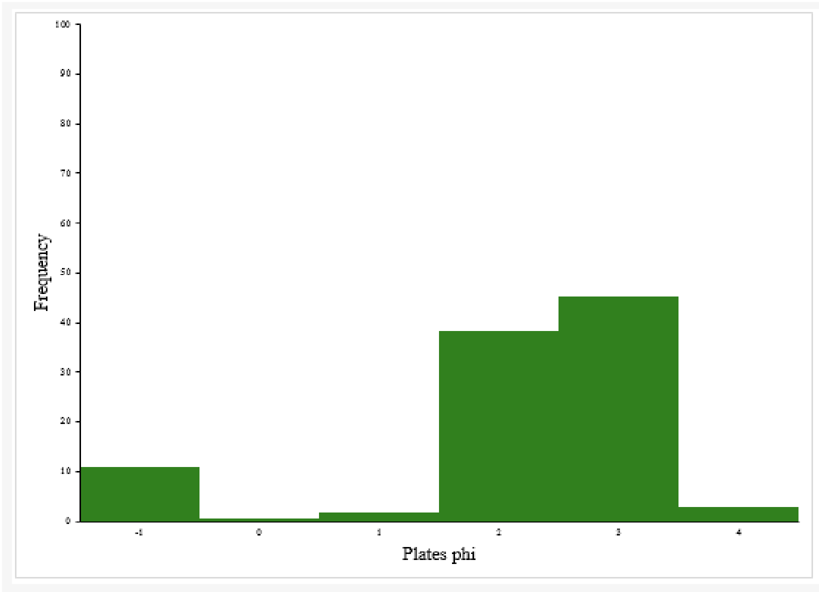

Figure G7. Frequency histogram of the particle grain size distribution for sample 1 from transect 3 in Cabo Rojo beach during sampling 2 (October/November 2016).

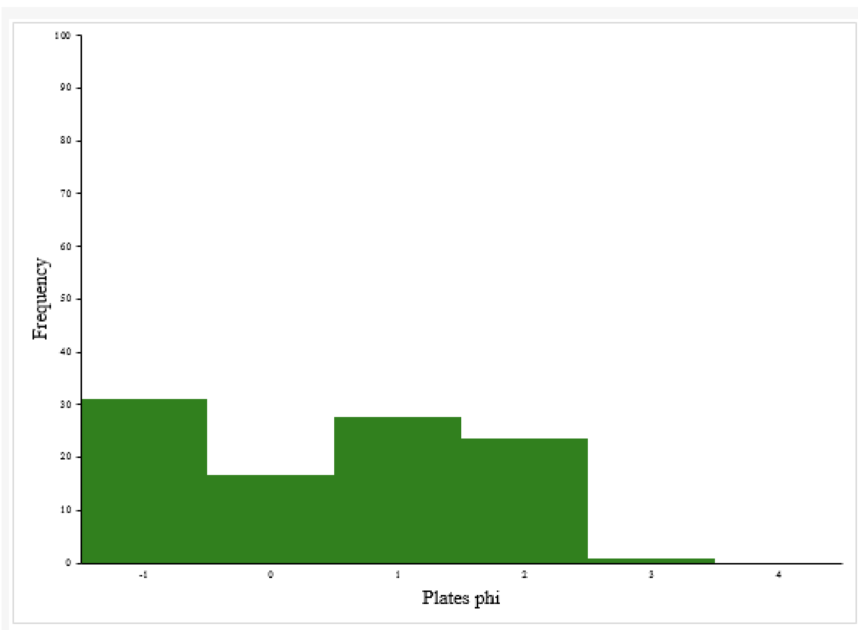

Figure G8. Frequency histogram of the particle grain size distribution for sample 4 from transect 3 in Cabo Rojo beach during sampling 2 (October/November 2016).

Table G9. Granulometry calculation of histograms for the particle grain size distribution for Transect 3, samples 1 and 4 at Cabo Rojo in sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 3			
Sample 1	-1	12.4	11.0
	0	0.6	0.5
	1	2	1.8
	2	43.2	38.4
	3	50.8	45.2
	4	3.4	3.0
	Total	112.4	
Sample 4	-1	31.6	31.1
	0	17	16.7
	1	28	27.6
	2	23.9	23.5
	3	1	0.9
	4	0	0
	Total	101.5	

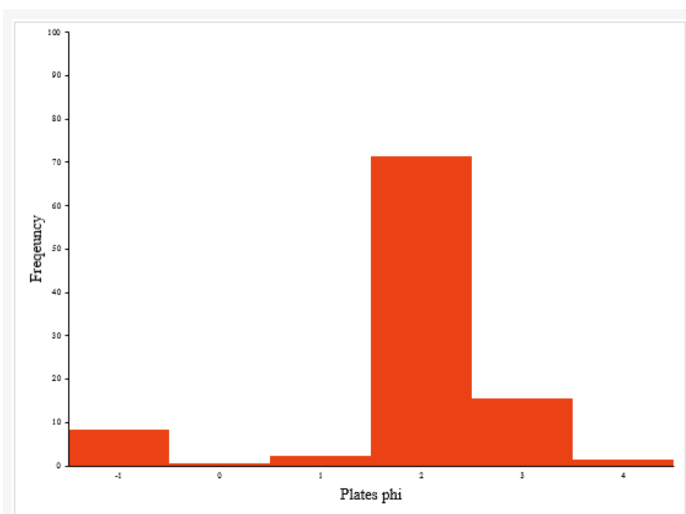

Figure G10. Frequency histogram of the particle grain size distribution for sample 1 from transect 4 in Cabo Rojo beach during sampling 2 (October/November 2016).

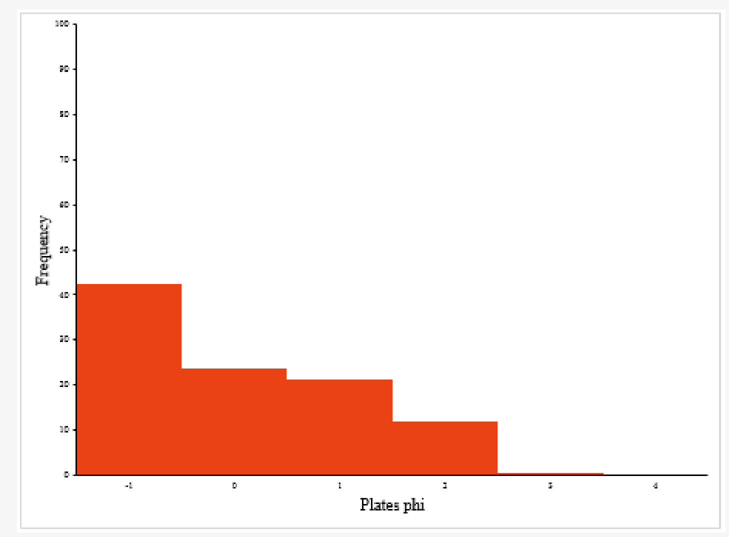

Figure G11. Frequency histogram of the particle grain size distribution for sample 4 from transect 4 in Cabo Rojo beach during sampling 2 (October/November 2016).

Table G12. Granulometry calculation of histograms for the particle grain size distribution for Transect 4, samples 1 and 4, at Cabo Rojo in sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 4			
Sample 1	-1	9.2	8.4
	0	0.8	0.7
	1	2.5	2.3
	2	77.8	71.3
	3	17.1	15.7
	4	1.7	1.5
	Total	109.1	
Sample 4	-1	47.6	42.4
	0	26.5	23.6
	1	23.8	21.2
	2	13.5	12.0
	3	0.8	0.7
	4	0	0
	Total	112.2	

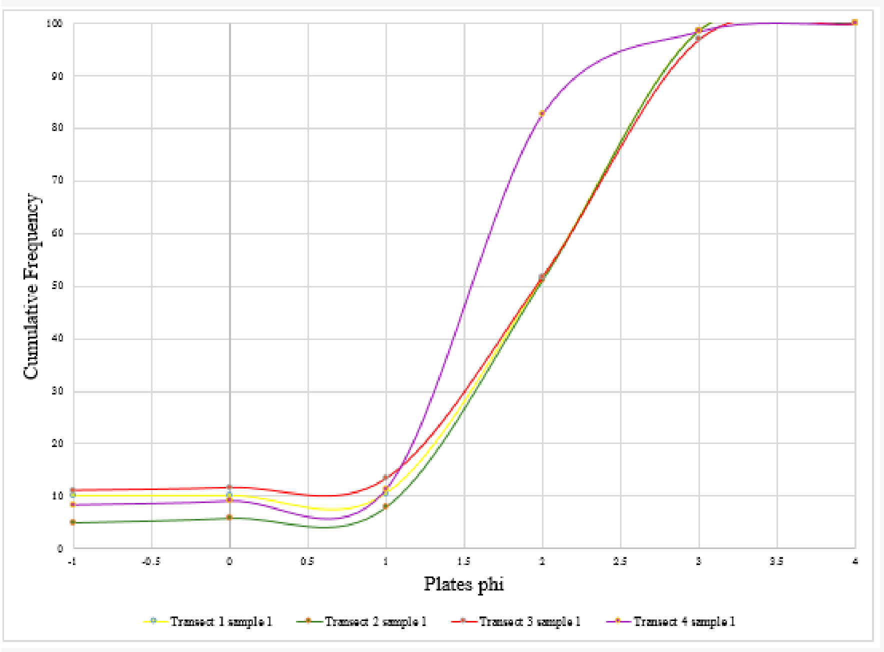

Figure G13. Cumulative frequency of the particle grain size distribution for sample 1 in all transects (T1, T2, T3, T4) at Cabo Rojo in sampling 2 (October/November 2016).

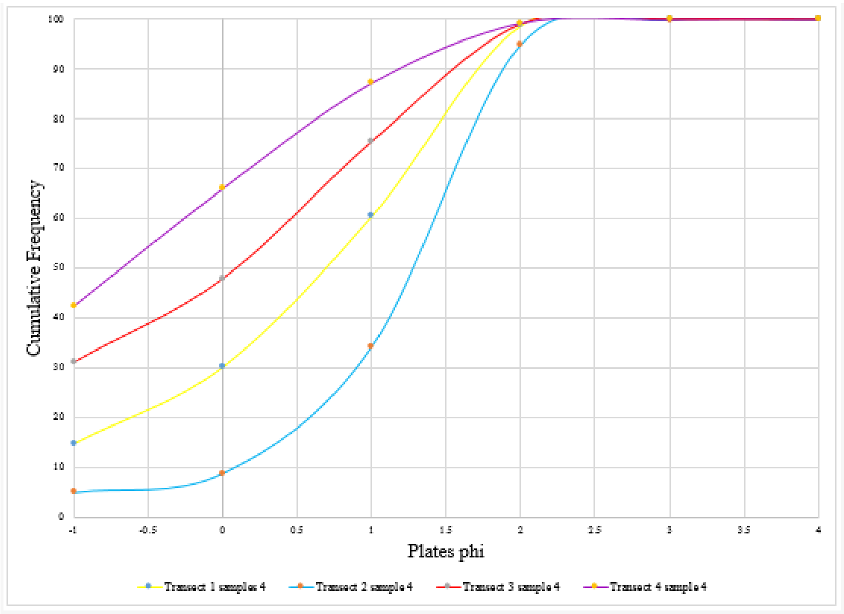

Figure G14. Cumulative frequency for the particle grain size distribution for sample 4 in all transects (T1, T2, T3, T4) at Cabo Rojo in sampling 2 (October/November 2016).

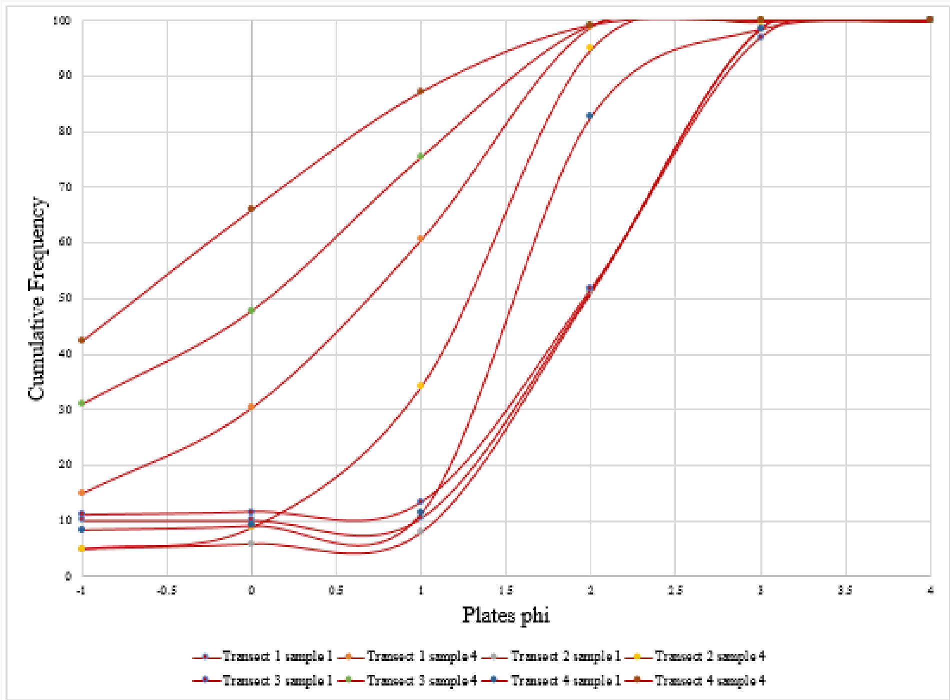

Figure G15. Cumulative frequency for the particle grain size distribution for all transects (T1, T2, T3, T4), samples 1 and 4 at Cabo Rojo in sampling 2 (October/November 2016).

Table G16. Granulometry calculation of cumulative frequency and histograms of the particle grain size distribution for all transects (T1, T2, T3, T4) in samples (1 and 4) in Cabo Rojo beach at sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency	Frequency
Transect 1			Cumulative curve	Histograms
Sample 1	-1	11.1	10.1	10.1
	0	0	10.1	0
	1	0.5	10.5	0.4
	2	45	51.5	40.9
	3	51.8	98.6	47.1
	4	1.5	100	1.4
	Total	109.9		
Sample 4	-1	15.7	14.9	14.9
	0	16.2	30.3	15.4
	1	31.9	60.5	30.3
	2	40.3	98.8	38.2
	3	1.3	100	1.2
	4	0	100	0
	Total	105.4		
Transect 2				
Sample 1	-1	5.1	4.9	4.9

	0	0.9	5.8	0.9
	1	2.2	7.9	2.1
	2	44.5	51.1	43.1
	3	49.2	98.6	47.5
	4	1.4	100	1.3
	Total	103.5		
Sample 4	-1	5.1	4.9	4.9
	0	4	8.8	3.9
	1	26.3	34.3	25.5
	2	62.6	94.9	60.6
	3	5.1	99.9	4.9
	4	0.1	100	0.1
	Total	103.2		
Transect 3				
Sample 1	-1	12.4	11.0	11.0
	0	0.6	11.6	0.5
	1	2	13.3	1.8
	2	43.2	51.8	38.4
	3	50.8	96.9	45.2
	4	3.4	100	3.0
	Total	112.4		
Sample 4	-1	31.6	31.1	31.1
	0	17	47.9	16.7
	1	28	75.5	27.6
	2	23.9	99.0	23.5
	3	1	100	0.9
	4	0	100	0
	Total	101.5		
Transect 4				
Sample 1	-1	9.2	8.4	8.4
	0	0.8	9.1	0.7
	1	2.5	11.4	2.3
	2	77.8	82.8	71.3
	3	17.1	98.4	15.7
	4	1.7	100	1.5
	Total	109.1		
Sample 4	-1	47.6	42.4	42.4
	0	26.5	66.0	23.6
	1	23.8	87.2	21.2
	2	13.5	99.3	12.0
	3	0.8	100	0.7

	4	0	100	0
	Total	112.2		

Appendix H

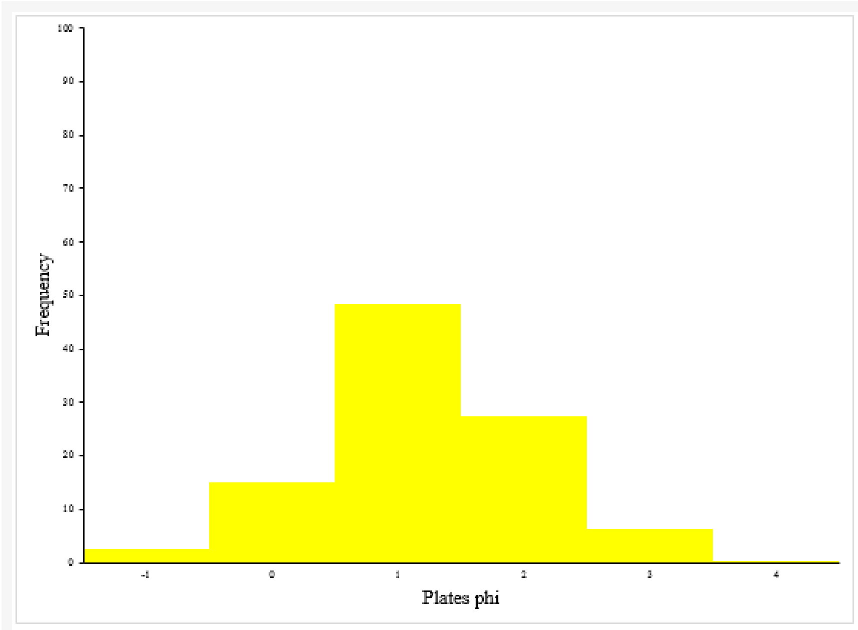

Figure H1. Frequency histogram of the particle grain size distribution for sample 1 from transect 1 in Rincón beach during sampling 2 (October/November 2016).

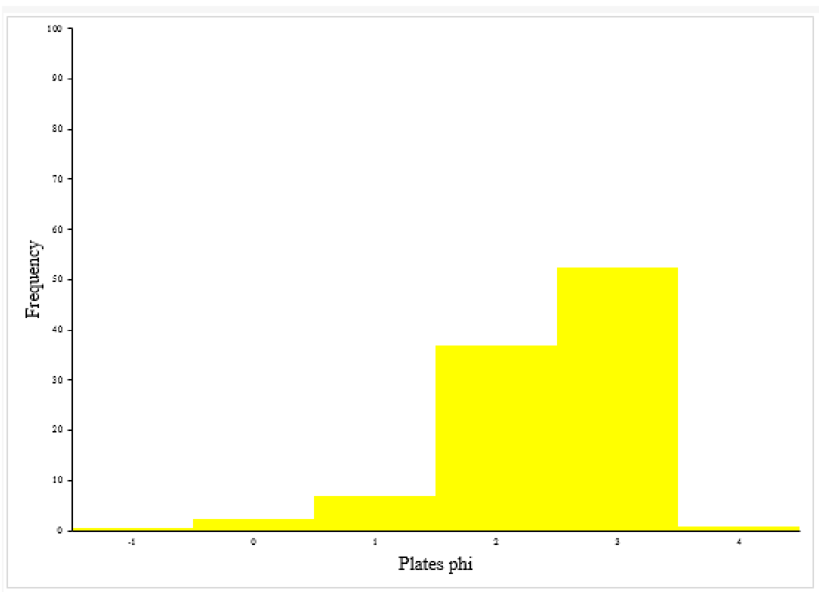

Figure H2. Frequency histogram of the particle grain size distribution for sample 4 from transect 1 in Rincón beach during sampling 2 (October/November 2016).

Table H3. Granulometry calculation of histograms for the particle grain size distribution for transect 1, samples 1 and 4, at Rincón in sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 1			
Sample 1	-1	2.7	2.7
	0	14.7	14.9
	1	47.8	48.5
	2	27	27.4
	3	6.2	6.3
	4	0.1	0.1
	Total	98.5	
Sample 4	-1	0.6	0.6
	0	2.2	2.2
	1	6.9	6.9
	2	36.5	36.8
	3	51.9	52.4
	4	1	1.0
	Total	99.1	

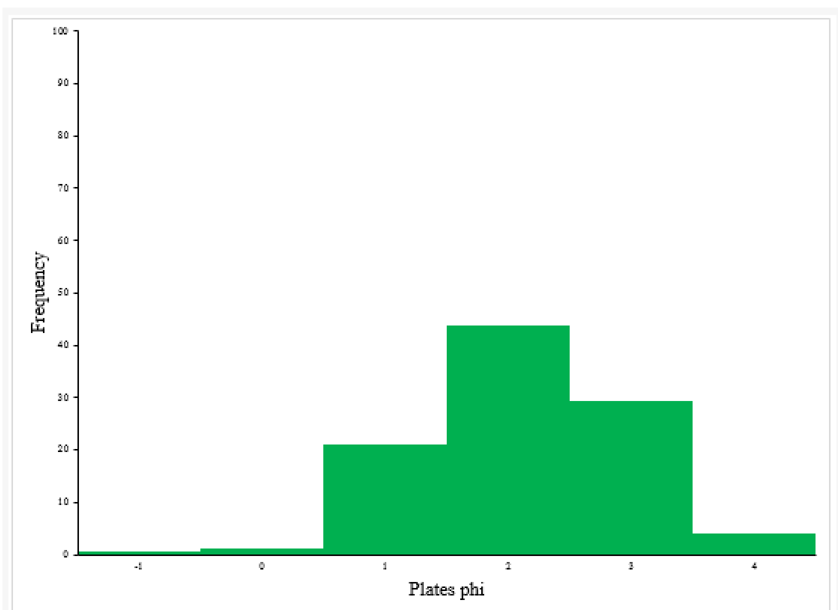

Figure H4. Frequency histogram of the particle grain size distribution for sample 1 from transect 2 in Rincón beach during sampling 2 (October/November 2016).

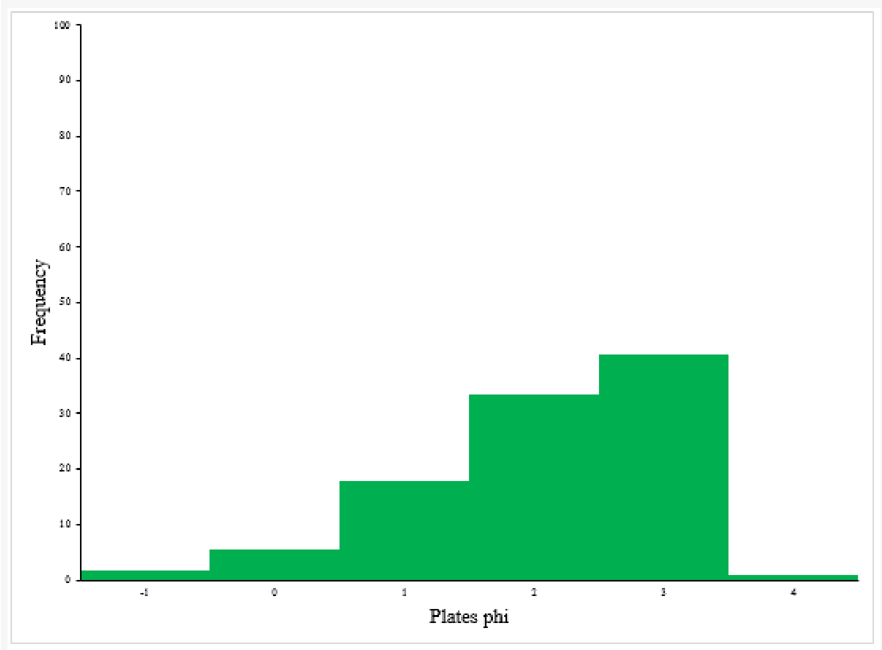

Figure H5. Frequency histogram of the particle grain size distribution for sample 4 from transect 2 in Rincón beach during sampling 2 (October/November 2016).

Table H6. Granulometry calculation of histograms for the particle grain size distribution for transect 2, samples 1 and 4, at Rincón in sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 2			
Sample 1	-1	0.7	0.7
	0	1.1	1.1
	1	20.9	21.0
	2	43.6	43.8
	3	29.2	29.3
	4	4	4.0
	Total	99.5	
Sample 4	-1	1.8	1.8
	0	5.3	5.4
	1	17.5	17.7
	2	32.9	33.4
	3	40.1	40.7
	4	1	1.0
	Total	98.6	

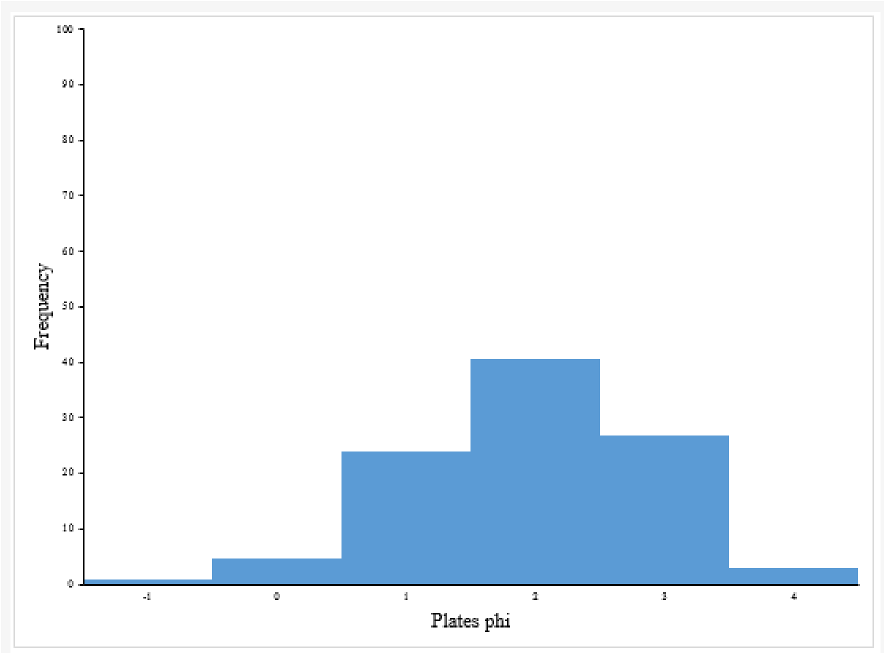

Figure H7. Frequency histogram of the particle grain size distribution for sample 1 from transect 3 in Rincón beach during sampling 2 (October/November 2016).

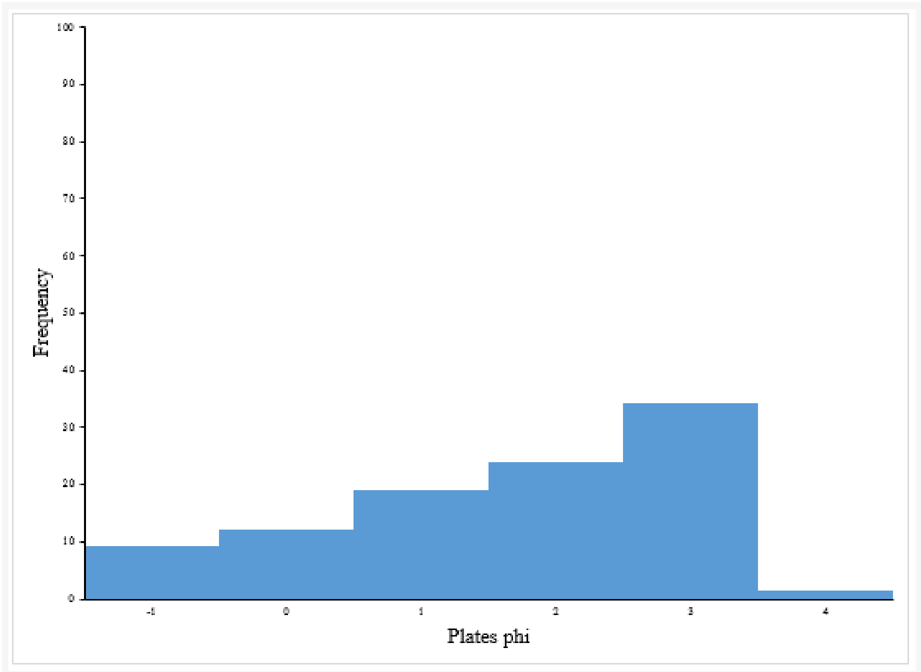

Figure H8. Frequency histogram of the particle grain size distribution for sample 4 from transect 3 in Rincón beach during sampling 2 (October/November 2016).

Table H9. Granulometry calculation of histograms for the particle grain size distribution for transect 3, samples 1 and 4 at Rincón in sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 3			
Sample 1	-1	0.9	0.9
	0	4.7	4.8
	1	23.5	23.9
	2	40	40.6
	3	26.3	26.7
	4	3	3.0
	Total	98.4	
Sample 4	-1	9	9.1
	0	12.1	12.2
	1	18.7	18.9
	2	23.5	23.8
	3	33.9	34.3
	4	1.5	1.5
	Total	98.7	

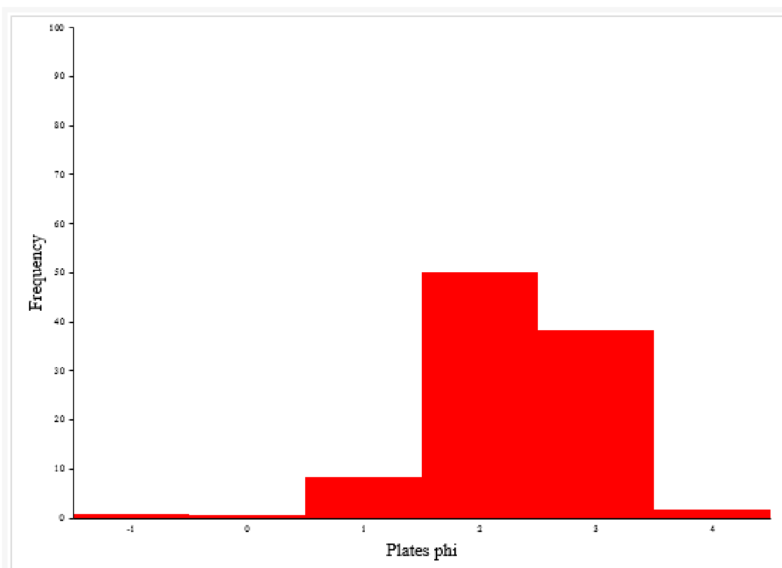

Figure H10. Frequency histogram of the particle grain size distribution for sample 1 from transect 4 in Rincón beach during sampling 2 (October/November 2016).

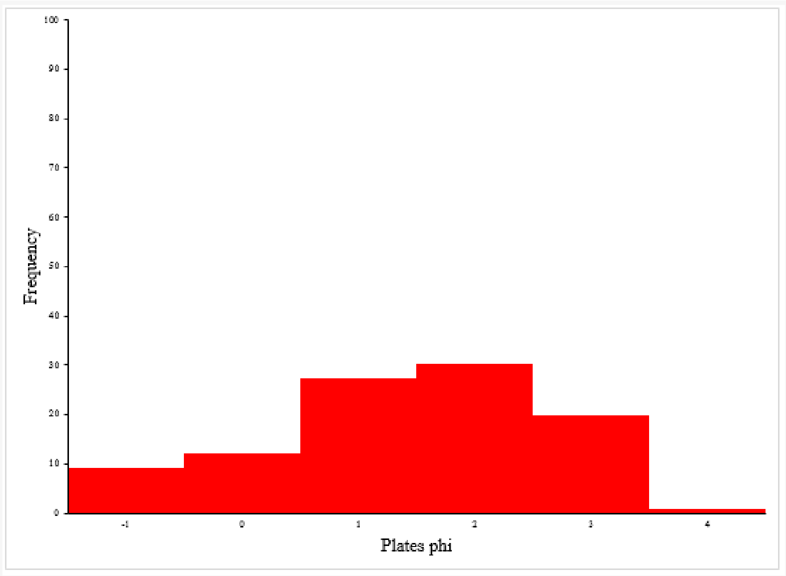

Figure H11. Frequency histogram of the particle grain size distribution for sample 4 from transect 4 in Rincón beach during sampling 2 (October/November 2016).

Table H12. Granulometry calculation of histograms for the particle grain size distribution for transect 4, samples 1 and 4, at Rincón in sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 4			
Sample 1	-1	0.8	0.8
	0	0.5	0.5
	1	8.4	8.4
	2	50.2	50.1
	3	38.5	38.5
	4	1.7	1.7
	Total	100.1	
Sample 4	-1	9.2	9.2
	0	12.1	12.1
	1	27.4	27.5
	2	30.2	30.3
	3	19.8	19.8
	4	1	1.0
	Total	99.7	

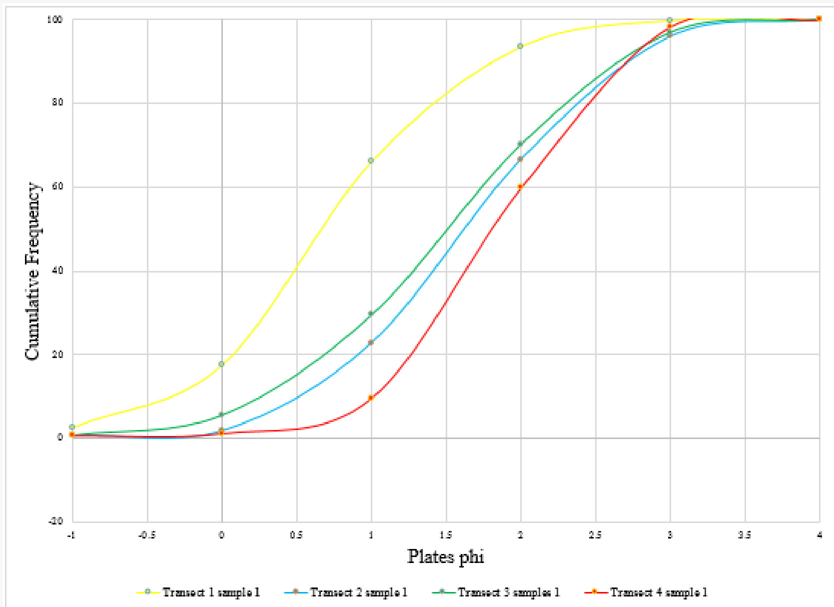

Figure H13. Cumulative frequency of the particle grain size distribution for sample 1 in all transects (T1, T2, T3, T4) at Rincón in sampling 2 (October/November).

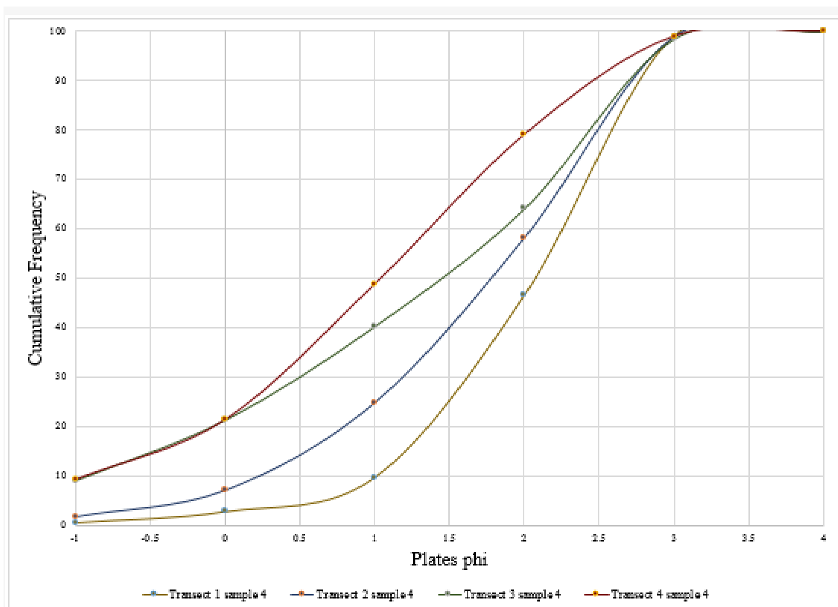

Figure H14. Cumulative frequency of the particle grain size distribution for sample 4 in all transects (T1, T2, T3, T4) at Rincón in sampling 2 (October/November 2016).

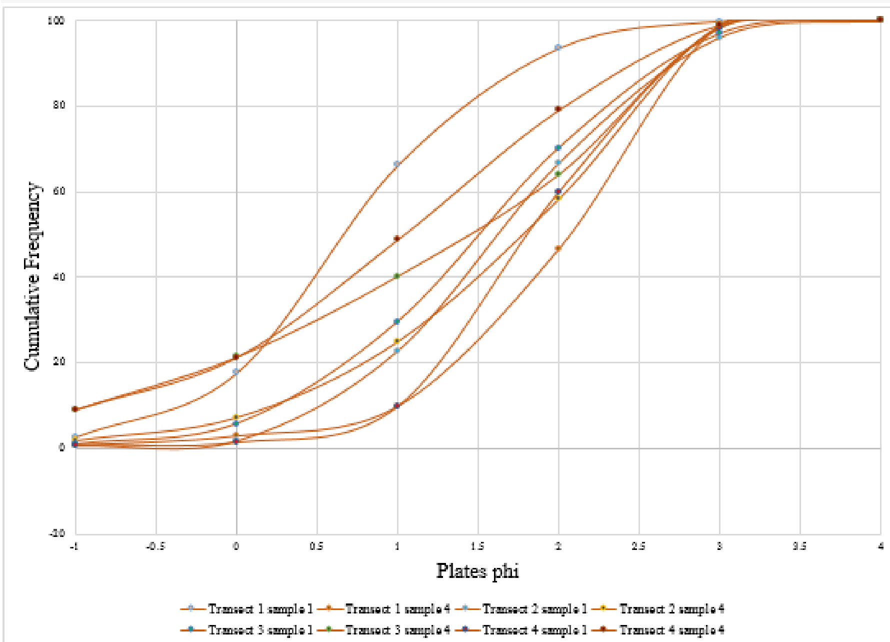

Figure H15. Cumulative frequency of the particle grain size distribution for all transects (T1, T2, T3, T4), samples 1 and 4 at Rincón in sampling 2 (October/November 2016).

Table H16. Granulometry calculation of cumulative frequency and histograms of the particle grain size distribution for all transects (T1, T2, T3, T4) in samples (1 and 4) in Rincón beach at sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency	Frequency
Transect 1			Cumulative curve	Histograms
Sample 1	-1	2.7	2.7	2.7
	0	14.7	17.7	14.9
	1	47.8	66.1	48.5
	2	27	93.6	27.4
	3	6.2	99.9	6.3
	4	0.1	100	0.1
	Total	98.5		
Sample 4	-1	0.6	0.6	0.6
	0	2.2	2.8	2.2
	1	6.9	9.8	6.9
	2	36.5	46.6	36.8
	3	51.9	98.9	52.3
	4	1	100	1.0
	Total	99.1		
Transect 2				
Sample 1	-1	0.7	0.7	0.7

	0	1.1	1.8	1.1
	1	20.9	22.8	21.0
	2	43.6	66.6	43.8
	3	29.2	95.9	29.3
	4	4	100	4.0
	Total	99.5		
Sample 4	-1	1.8	1.8	1.8
	0	5.3	7.2	5.4
	1	17.5	24.9	17.7
	2	32.9	58.3	33.4
	3	40.1	98.9	40.7
	4	1	100	1.0
	Total	98.6		
Transect 3				
Sample 1	-1	0.9	0.9	0.9
	0	4.7	5.79	4.8
	1	23.5	29.6	23.9
	2	40	70.2	40.6
	3	26.3	96.9	26.7
	4	3	100	3.0
	Total	98.4		
Sample 4	-1	9	9.1	9.1
	0	12.1	21.4	12.2
	1	18.7	40.3	18.9
	2	23.5	64.1	23.8
	3	33.9	98.5	34.3
	4	1.5	100	1.5
	Total	98.7		
Transect 4				
Sample 1	-1	0.8	0.8	0.8
	0	0.5	1.3	0.5
	1	8.4	9.7	8.4
	2	50.2	59.8	50.1
	3	38.5	98.3	38.5
	4	1.7	100	1.7
	Total	100.1		
Sample 4	-1	9.2	9.2	9.2
	0	12.1	21.4	12.1
	1	27.4	48.8	27.5
	2	30.2	79.1	30.3
	3	19.8	98.9	19.8

	4	1	100	1.0
	Total	99.7		

Appendix I

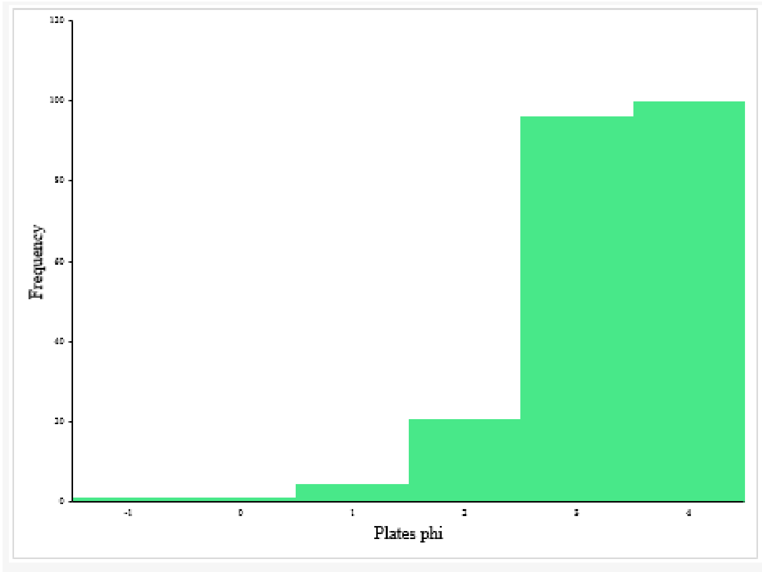

Figure I1. Frequency histogram of the particle grain size distribution for sample 1 from transect 1 in Mayagüez beach during sampling 2 (October/November 2016).

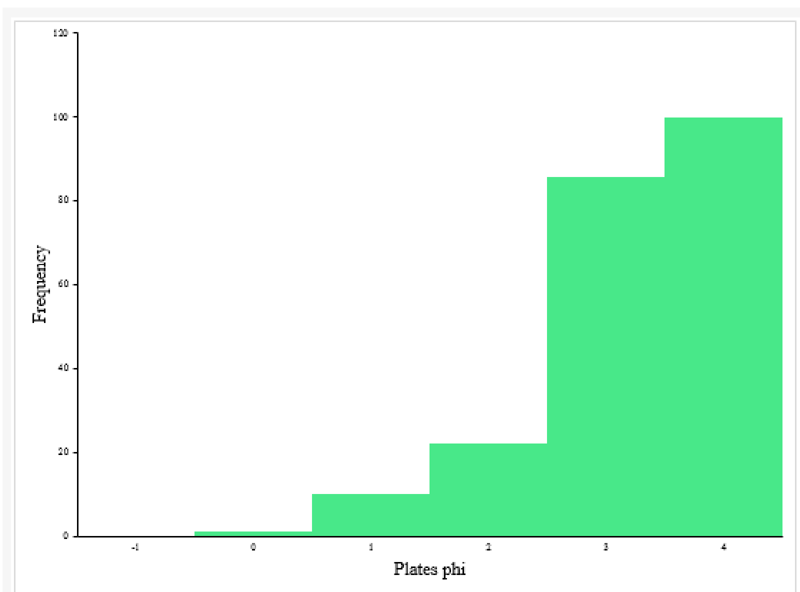

Figure I2. Frequency histogram of the particle grain size distribution for sample 4 from transect 1 in Mayagüez beach during sampling 2 (October/November 2016).

Table I3. Granulometry calculation of histograms of particle grain size distribution for Transect 1, samples 1 and 4, at Mayagüez in sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 1			
Sample 1	-1	1	1.0
	0	0.3	0.3
	1	3.3	3.3
	2	16.2	16.2
	3	75	75.1
	4	4	4.0
	Total	99.8	
Sample 4	-1	0	0
	0	1.2	1.2
	1	8.7	8.8
	2	12	12.1
	3	63.1	63.6
	4	14.2	14.3
	Total	99.2	

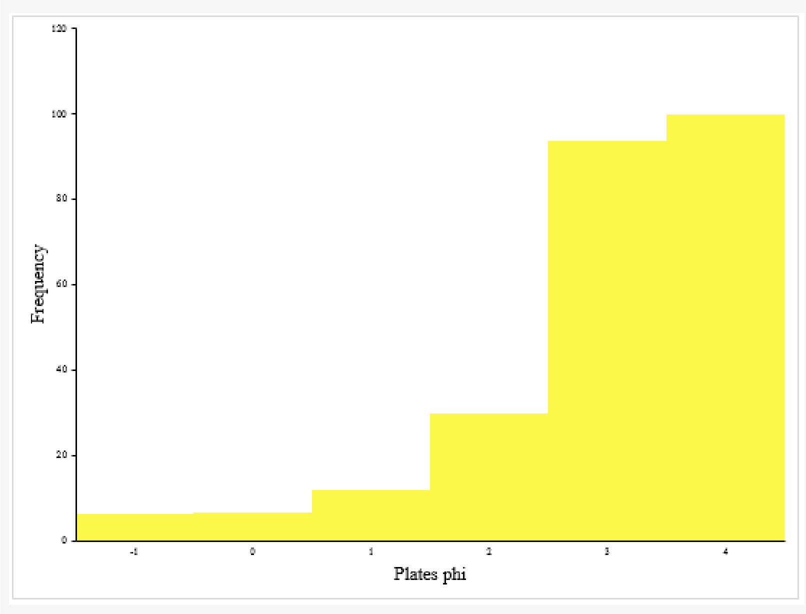

Figure I4. Frequency histogram of the particle grain size distribution for sample 1 from transect 2 in Mayagüez beach during sampling 2 (October/November 2016).

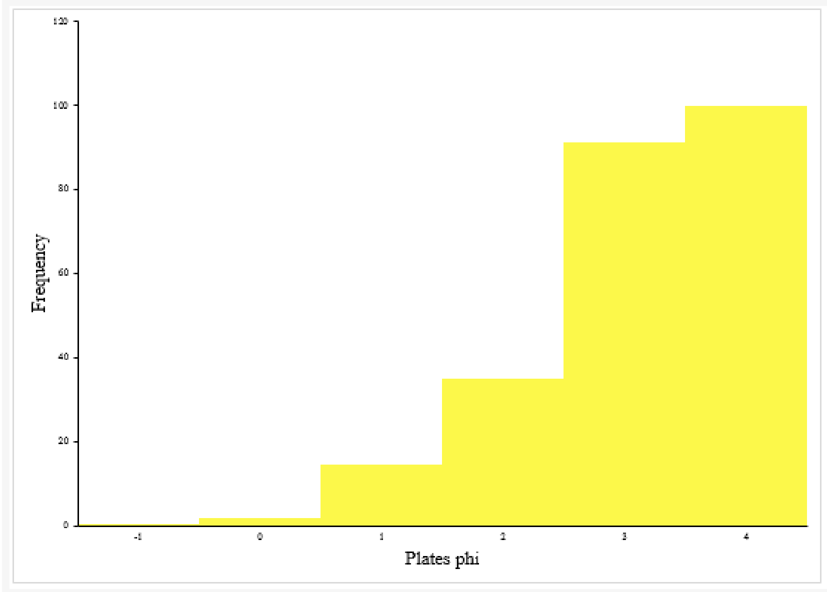

Figure I5. Frequency histogram of the particle grain size distribution for sample 4 from transect 2 in Mayagüez beach during sampling 2 (October/November 2016).

Table I6. Granulometry calculation of histograms for the particle grain size distribution for transect 2, samples 1 and 4, at Mayagüez in sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 2			
Sample 1	-1	6.5	6.2
	0	0.3	0.3
	1	5.5	5.2
	2	18.8	17.9
	3	67.3	64.1
	4	6.6	6.3
	Total	105	
Sample 4	-1	0.4	0.4
	0	1.5	1.5
	1	12.5	12.7
	2	19.9	20.2
	3	55.6	56.4
	4	8.6	8.7
	Total	98.5	

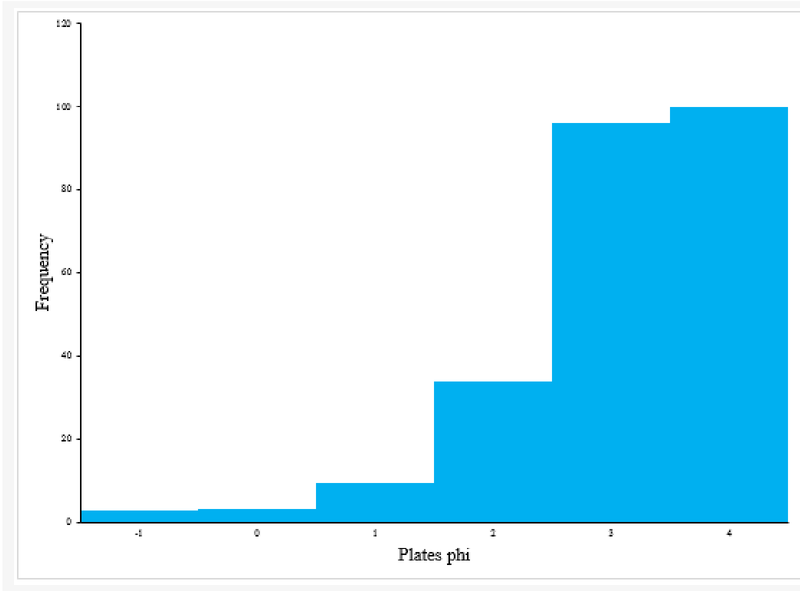

Figure I7. Frequency histogram of the particle grain size distribution for sample 1 from transect 3 in Mayagüez beach during sampling 2 (October/November 2016).

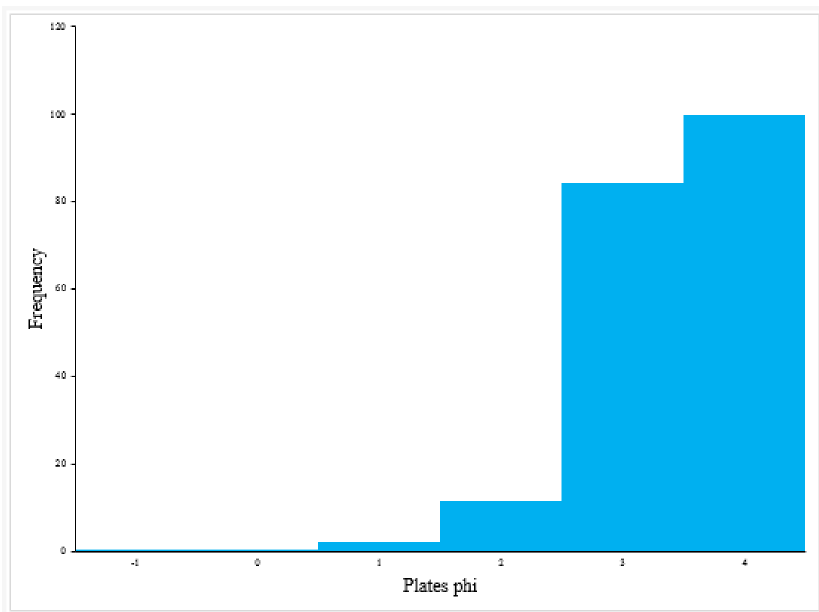

Figure I8. Frequency histogram of the particle grain size distribution for sample 4 from transect 3 in Mayagüez beach during sampling 2 (October/November 2016).

Table I9. Granulometry calculation of histograms for the particle grain size distribution for transect 3, samples 1 and 4 at Mayagüez in sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 3			
Sample 1	-1	3	2.9
	0	0.2	0.2

	1	6.3	6.1
	2	25.3	24.6
	3	63.8	62.1
	4	4.1	3.9
	Total	102.7	
Sample 4	-1	0.3	0.3
	0	0.1	0.1
	1	1.6	1.6
	2	9.4	9.5
	3	72.2	72.7
	4	15.7	15.8
	Total	99.3	

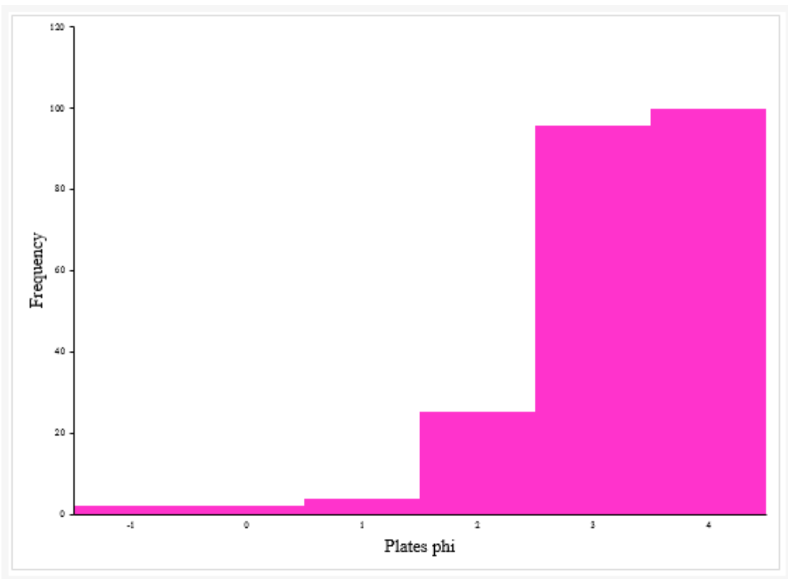

Figure I10. Frequency histogram of the particle grain size distribution for sample 1 from transect 4 in Mayagüez beach during sampling 2 (October/November 2016).

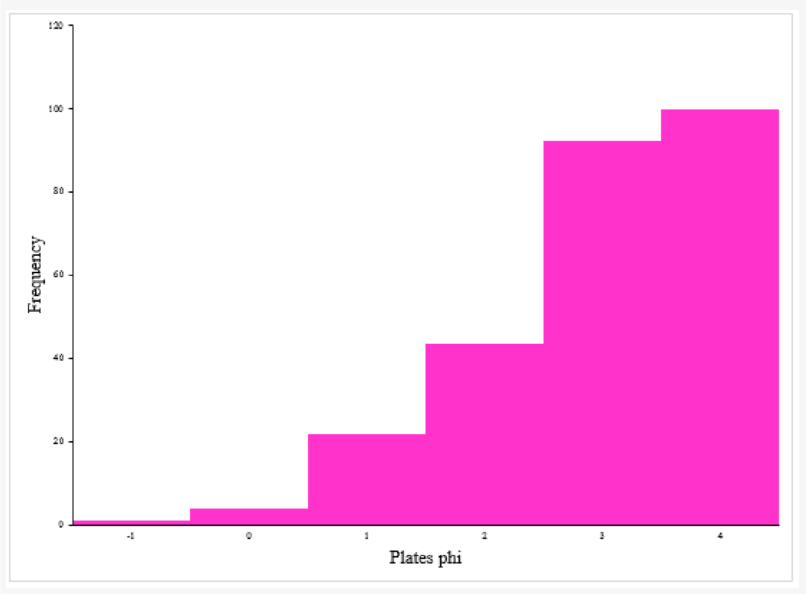

Figure I11. Frequency histogram of the particle grain size distribution for sample 4 from transect 4 in Mayagüez beach during sampling 2 (October/November 2016).

Table I12. Granulometry calculation of histograms for the particle grain size distribution for transect 4, samples 1 and 4, at Mayagüez in sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency
Transect 4			
Sample 1	-1	2.1	2.1
	0	0	0
	1	1.8	1.8
	2	21.8	21.5
	3	71.5	70.4
	4	4.3	4.2
	Total	101.5	
Sample 4	-1	1	1.0
	0	3	3.0
	1	17.6	17.8
	2	21.7	21.9
	3	48.1	48.6
	4	7.6	7.7
	Total	99	

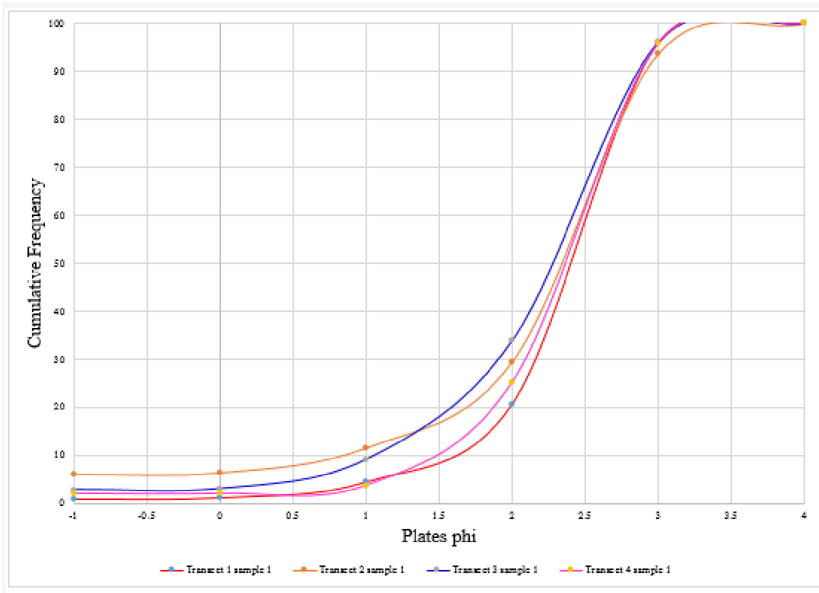

Figure I13. Cumulative frequency of particle grain size distribution for sample 1 in all transects (T1, T2, T3, T4) at Mayagüez beach in sampling 2 (October/November 2016).

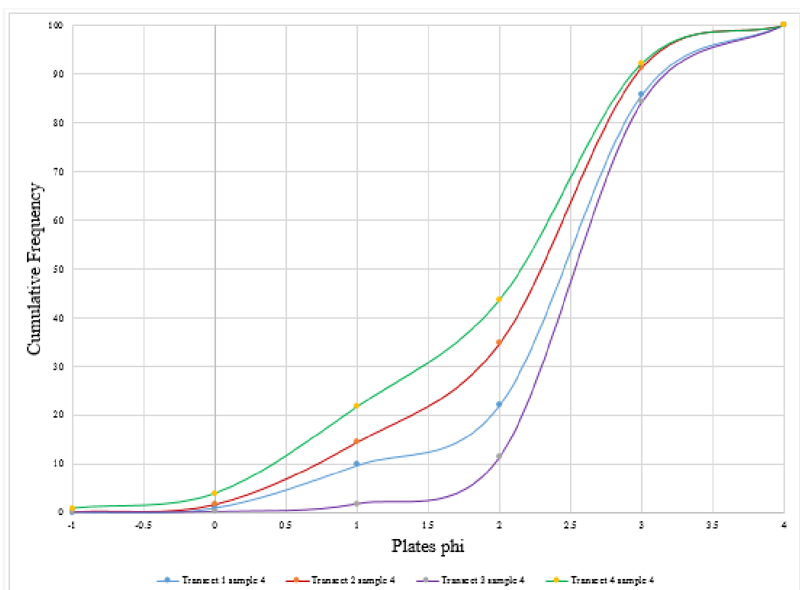

Figure I14. Cumulative frequency of particle grain size distribution for sample 4 in all transects (T1, T2, T3, T4) at Mayagüez in sampling 2 (October/November 2016).

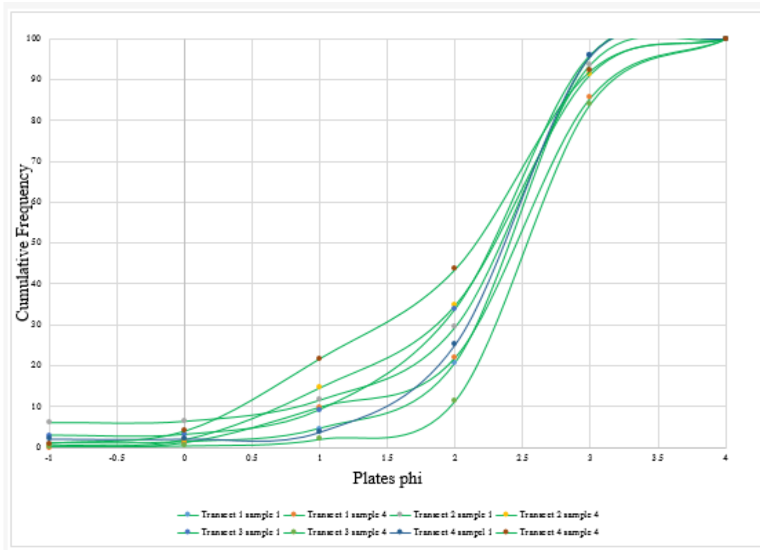

Figure I15. Cumulative frequency of particle grain size distribution for all transects (T1, T2, T3, T4), and samples (1 and 4) from Mayagüez beach in sampling 2 (October/November 2016).

Table I16. Granulometry calculation of cumulative frequency and histograms of particle grain size distribution for all transects (T1, T2, T3, T4) and samples (1 and 4) from Mayagüez beach at sampling 2 (October/November 2016).

Transect	Plates phi	Weight (grams)	Frequency	Frequency
Transect 1			Cumulative curve	Histograms
Sample 1	-1	1	1.0	1.0
	0	0.3	1.3	0.3
	1	3.3	4.6	3.3
	2	16.2	20.8	16.2
	3	75	95.9	75.1
	4	4	100	4.0
	Total	99.8		
Sample 4	-1	0	0	0
	0	1.2	1.2	1.2
	1	8.7	9.9	8.8
	2	12	22.1	12.1
	3	63.1	85.7	63.6
	4	14.2	100	14.3
	Total	99.2		
Transect 2				
Sample 1	-1	6.5	6.2	6.2
	0	0.3	6.5	0.3
	1	5.5	11.7	5.2

	2	18.8	29.6	17.9
	3	67.3	93.7	64.1
	4	6.6	100	6.3
	Total	105		
Sample 4	-1	0.4	0.4	0.4
	0	1.5	1.9	1.5
	1	12.5	14.6	12.7
	2	19.9	34.8	20.2
	3	55.6	91.3	56.4
	4	8.6	100	8.7
	Total	98.5		
Transect 3				
Sample 1	-1	3	2.9	2.9
	0	0.2	3.1	0.2
	1	6.3	9.2	6.1
	2	25.3	33.9	24.6
	3	63.8	96.0	62.1
	4	4.1	100	3.9
	Total	102.7		
Sample 4	-1	0.3	0.3	0.3
	0	0.1	0.4	0.1
	1	1.6	2.0	1.6
	2	9.4	11.5	9.5
	3	72.2	84.2	72.7
	4	15.7	100	15.8
	Total	99.3		
Transect 4				
Sample 1	-1	2.1	2.1	2.1
	0	0	2.1	0
	1	1.8	3.8	1.8
	2	21.8	25.3	21.5
	3	71.5	95.8	70.4
	4	4.3	100	4.2
	Total	101.5		
Sample 4	-1	1	1.0	1.0
	0	3	4.0	3.0
	1	17.6	21.8	17.8
	2	21.7	43.7	21.9
	3	48.1	92.3	48.6
	4	7.6	100	7.7
	Total	99		

Appendix J

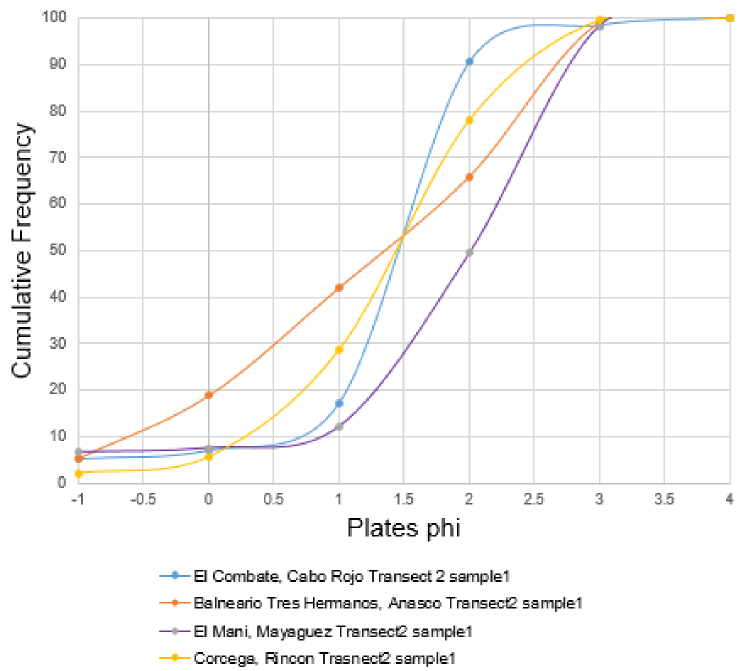

Figure J1. Cumulative frequency of the particle grain size distribution for Transects 2 in sample 1 at all beaches in sampling 1 (August/September 2016).

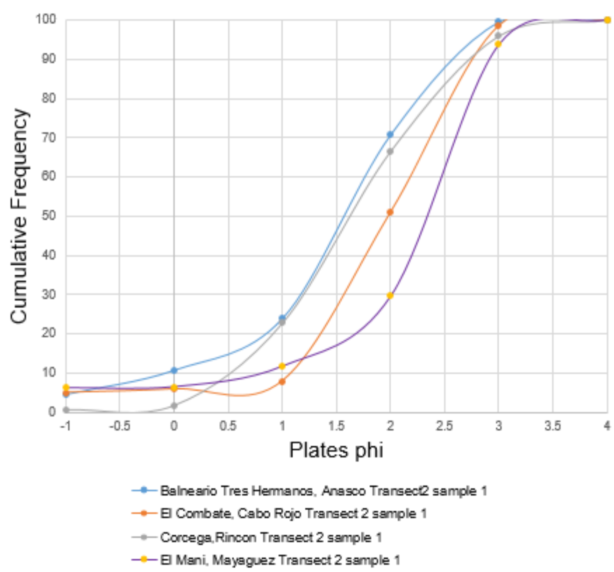

Figure J2. Cumulative frequency of the particle grain size distribution for transects 2 in sample 1 at all beaches in sampling 2 (October/November 2016).

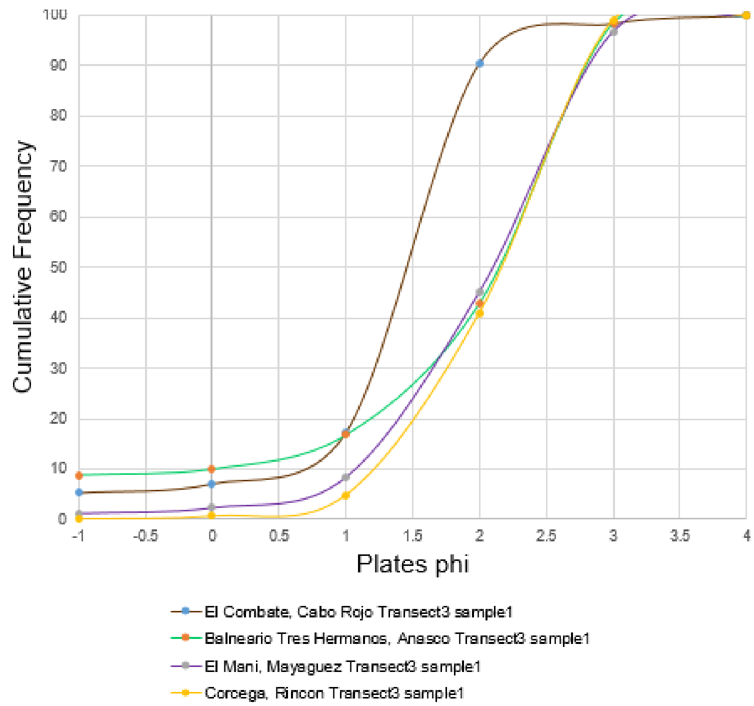

Figure J3. Cumulative frequency of the particle grain size distribution for transect 3 in sample 1 at all beaches in sampling 1 (August/September 2016).

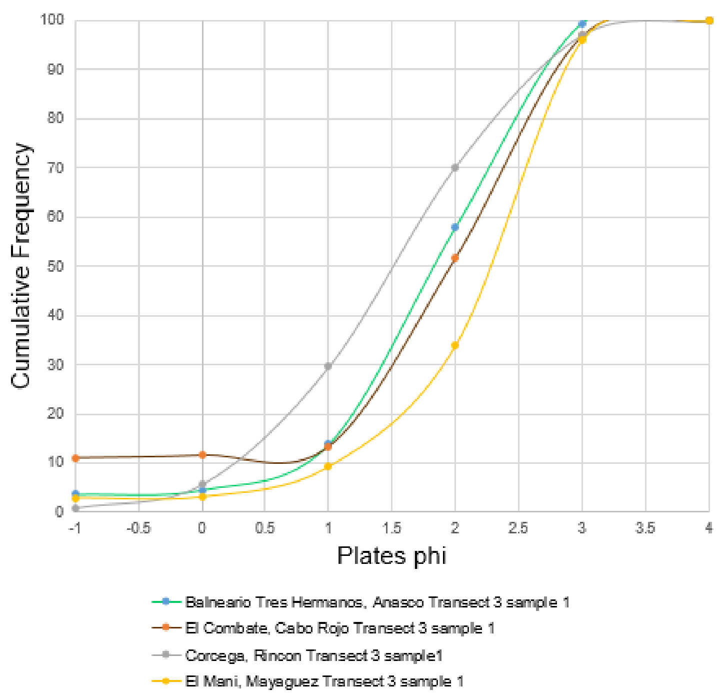

Figure J4. Cumulative frequency of the particle grain size distribution for transects 3 in sample 1 at all beaches in sampling 2 (October/November 2016).

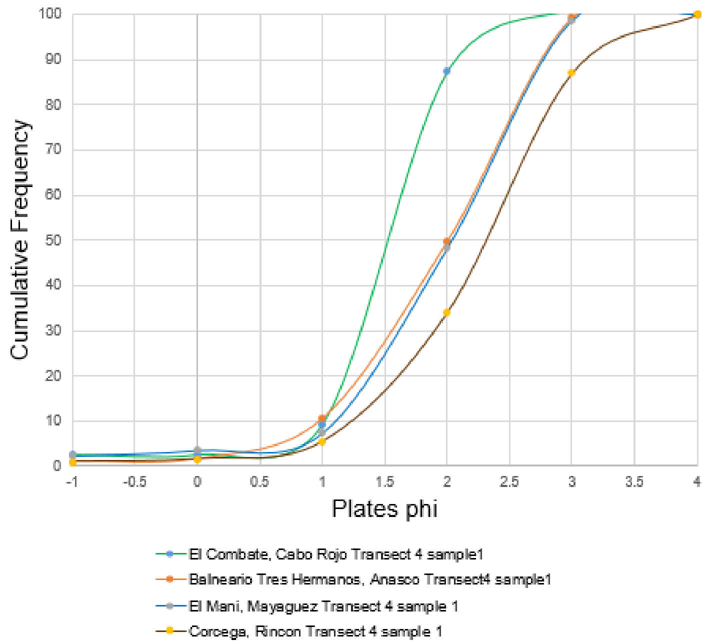

Figure J5. Cumulative frequency of the particle grain size distribution for transect 4 in sample 1 at all beaches in sampling 1 (August/September 2016).

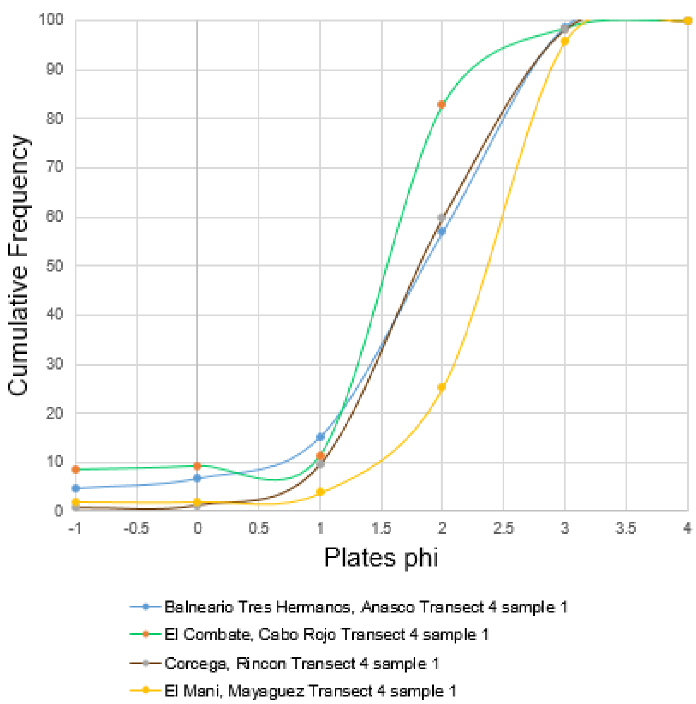

Figure J6. Cumulative frequency of the particle grain size distribution for transect 4 in sample 1 at all beaches in sampling 2 (October/November 2016).

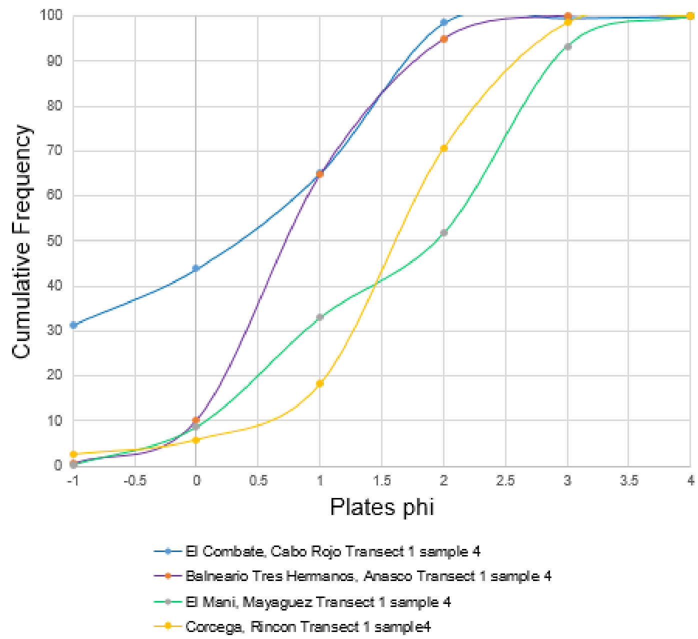

Figure J7. Cumulative frequency of the particle grain size distribution for transect 1 in sample 4 at all beaches in sampling 1 (August/September 2016).

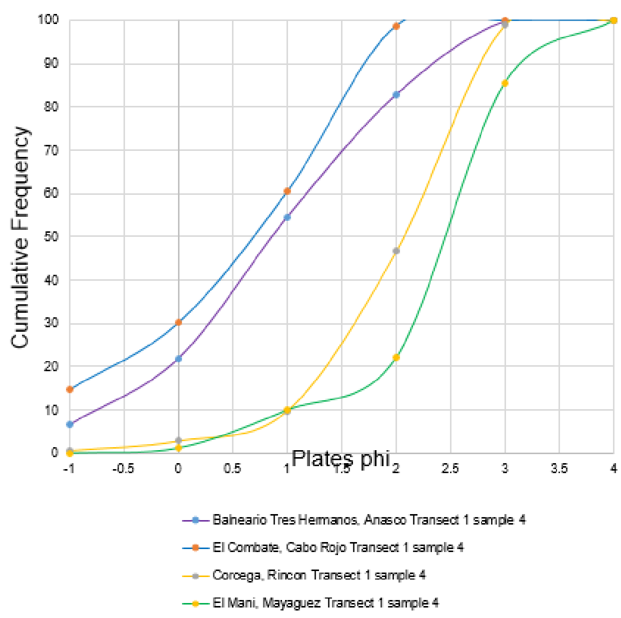

Figure J8. Cumulative frequency of the particle grain size distribution for transect 1 in sample 4 at all beaches in sampling 2 (October/November 2016).

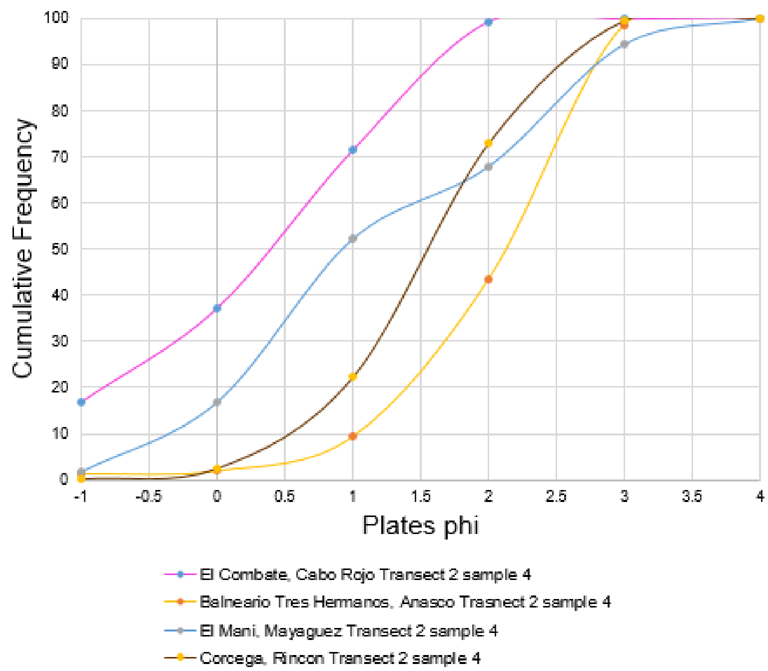

Figure J9. Cumulative frequency of the particle grain size distribution for transect 2 in sample 4 at all beaches in sampling 1 (August/September 2016).

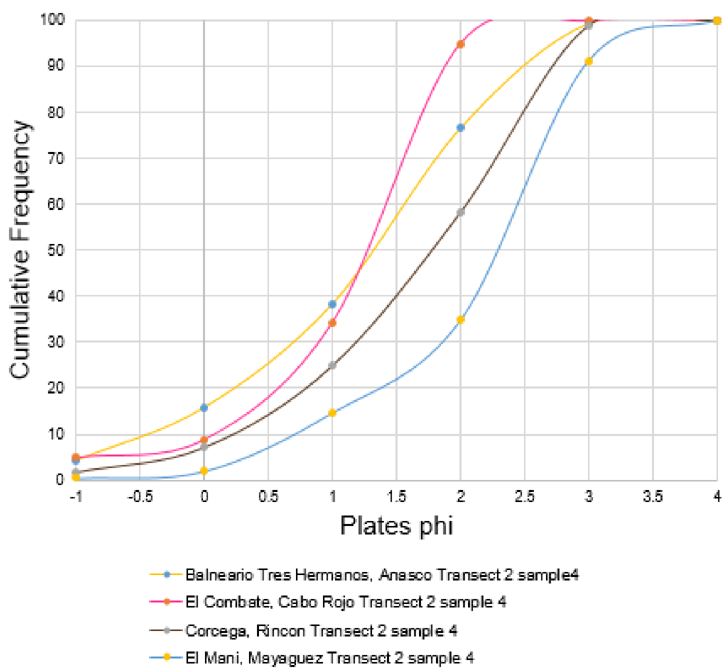

Figure J10. Cumulative frequency of the particle grain size distribution for transect 2 in sample 4 at all beaches in sampling 2 (October/November 2016).

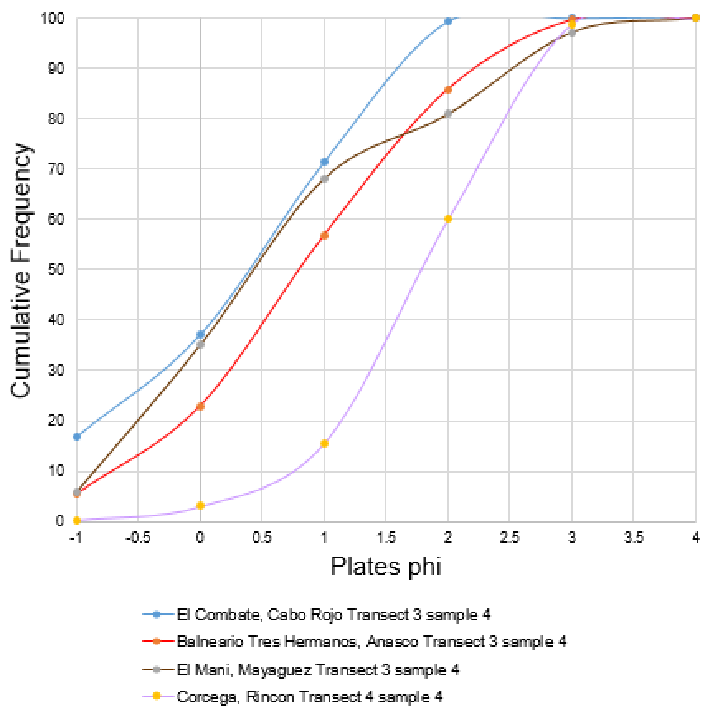

Figure J11. Cumulative frequency of the particle grain size distribution for transect 3 in sample 4 at all beaches in sampling 1 (August/September 2016).

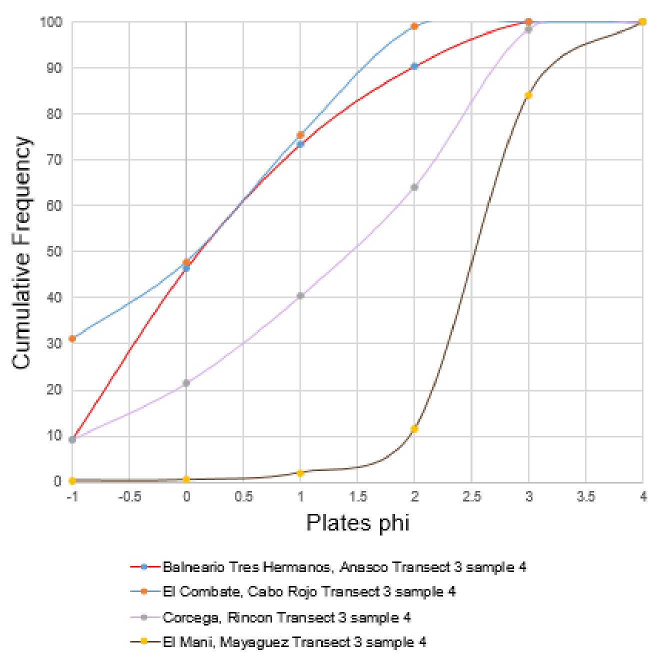

Figure J12. Cumulative frequency of the particle grain size distribution for transect 3 in sample 4 at all beaches in sampling 2 (October/November 2016).

Appendix K

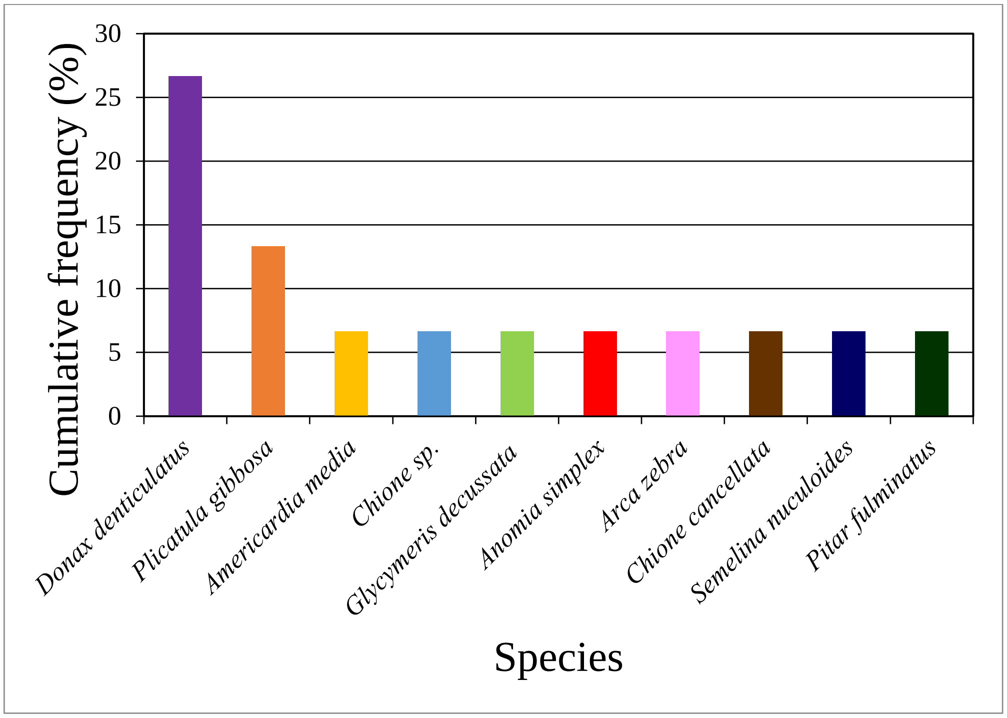

Figure K1. Cumulative frequency (%) of bivalves species at Combate, Cabo Rojo in August 26, 2016 (n=4).

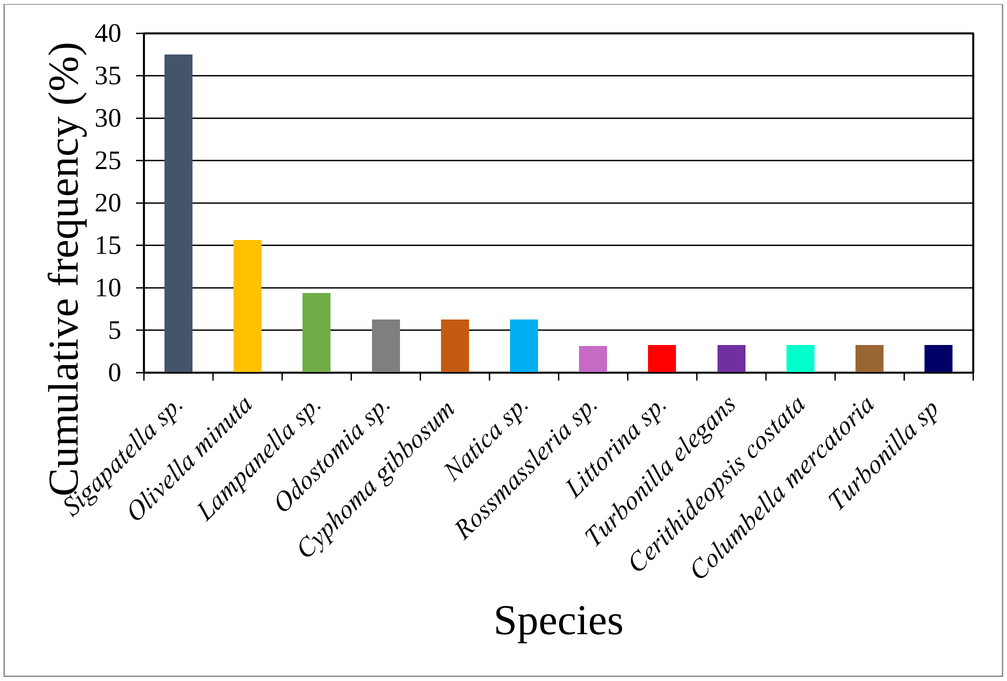

Figure K2. Cumulative frequency (%) of gastropods species at Combate, Cabo Rojo in August 26, 2016 (n=4).

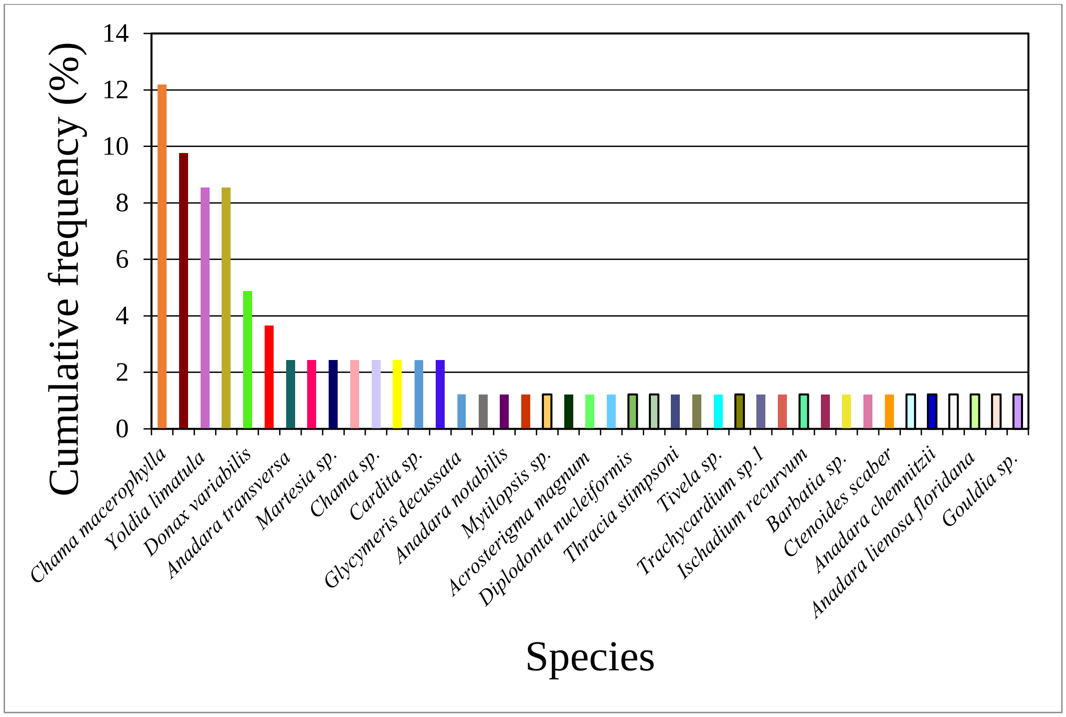

Figure K3. Cumulative frequency (%) of bivalves species at Añasco beach in August 31, 2016 (n=4).

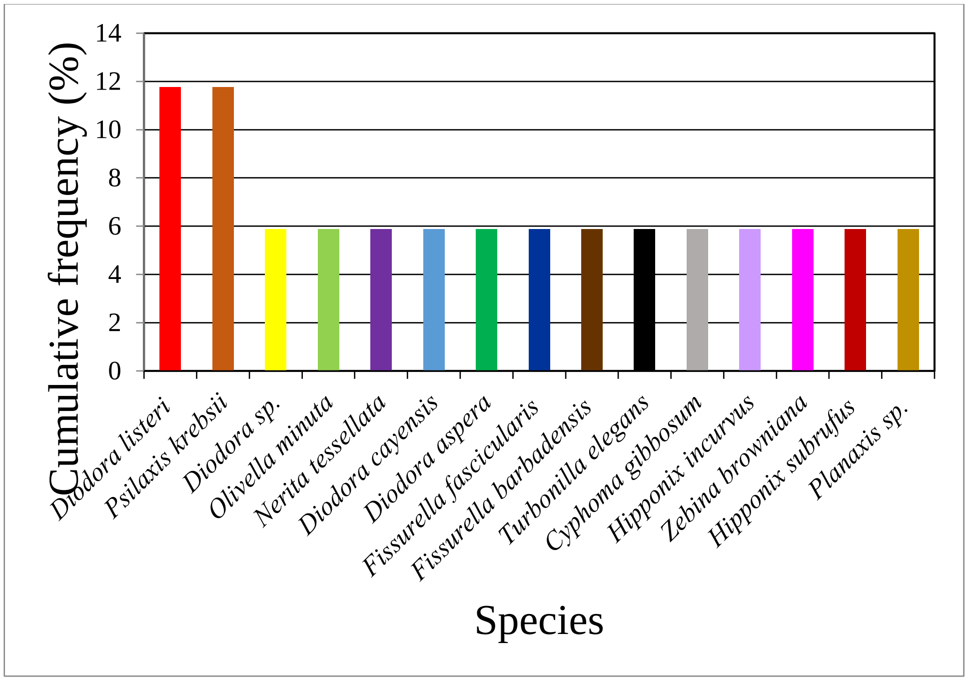

Figure K4. Cumulative frequency (%) of gastropods species at Añasco beach in August 31, 2016 (n=4).

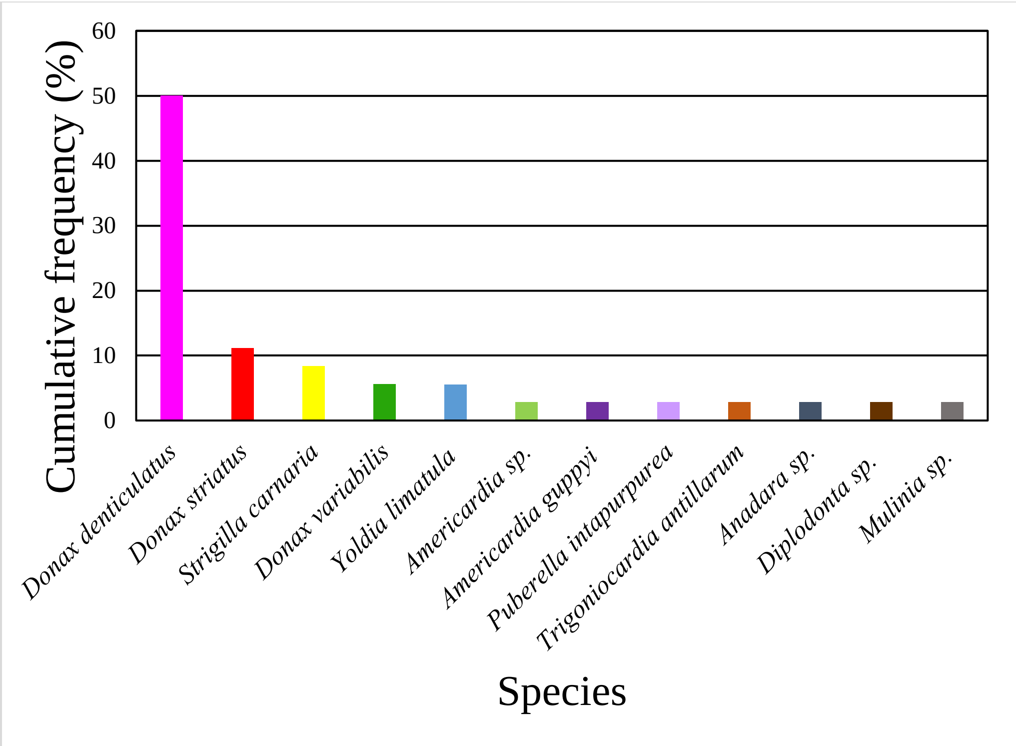

Figure K5. Cumulative frequency (%) of bivalves species at El Maní, Mayagüez in September 2, 2016 (n=4).

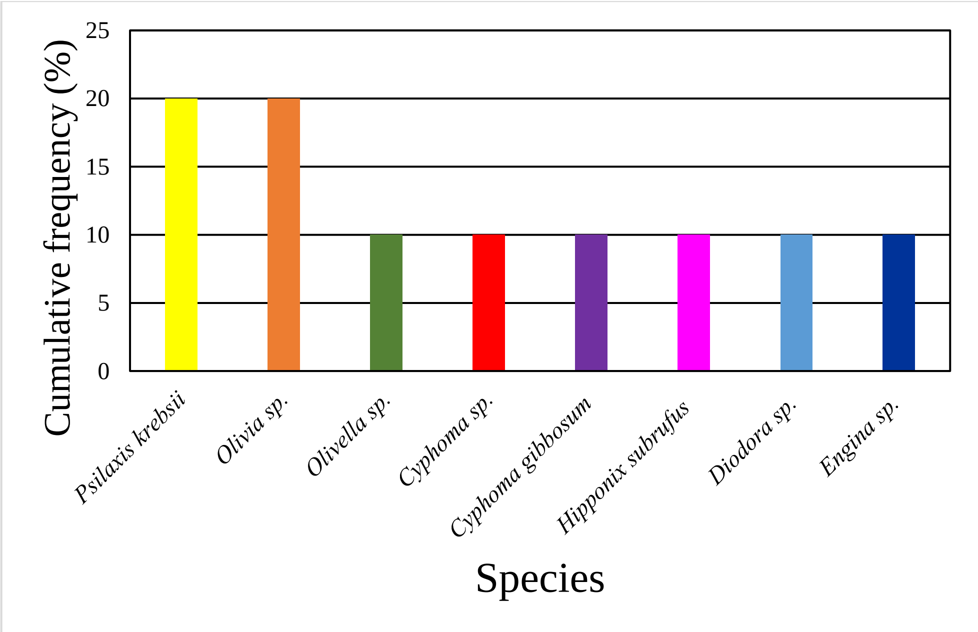

Figure K6. Cumulative frequency (%) of gastropods species at Córcega, Rincón in September 16, 2016 (n=4).

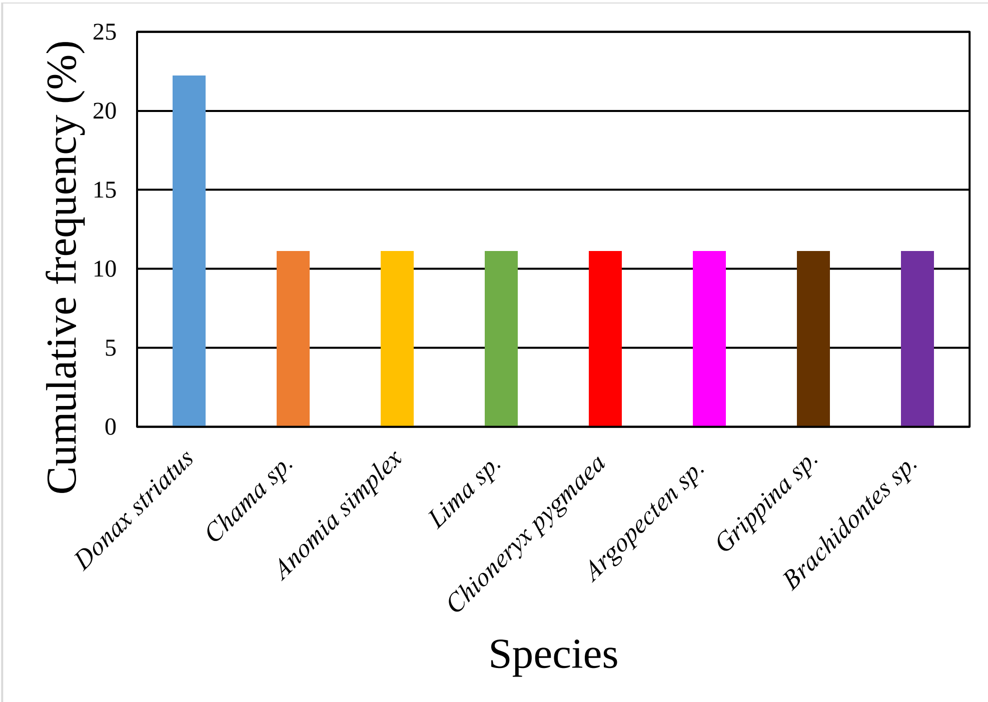

Figure K7. Cumulative frequency (%) of bivalves species at Córcega, Rincón in September 16, 2016 (n=4).

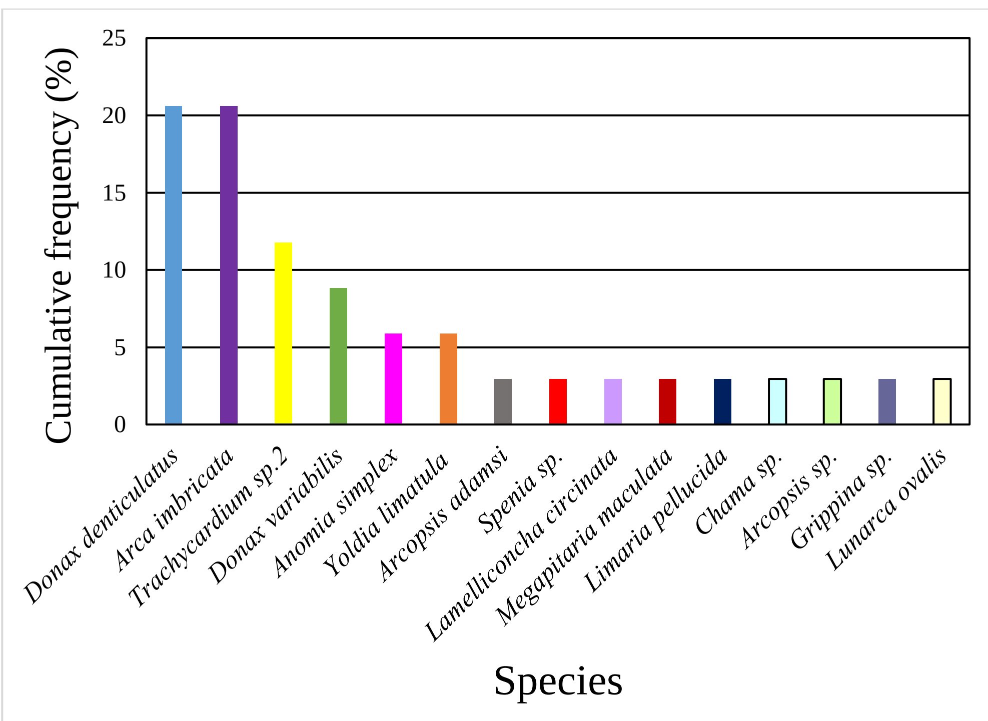

Figure K8. Cumulative frequency (%) of bivalves species at Añasco in October 15, 2016 (n=4).

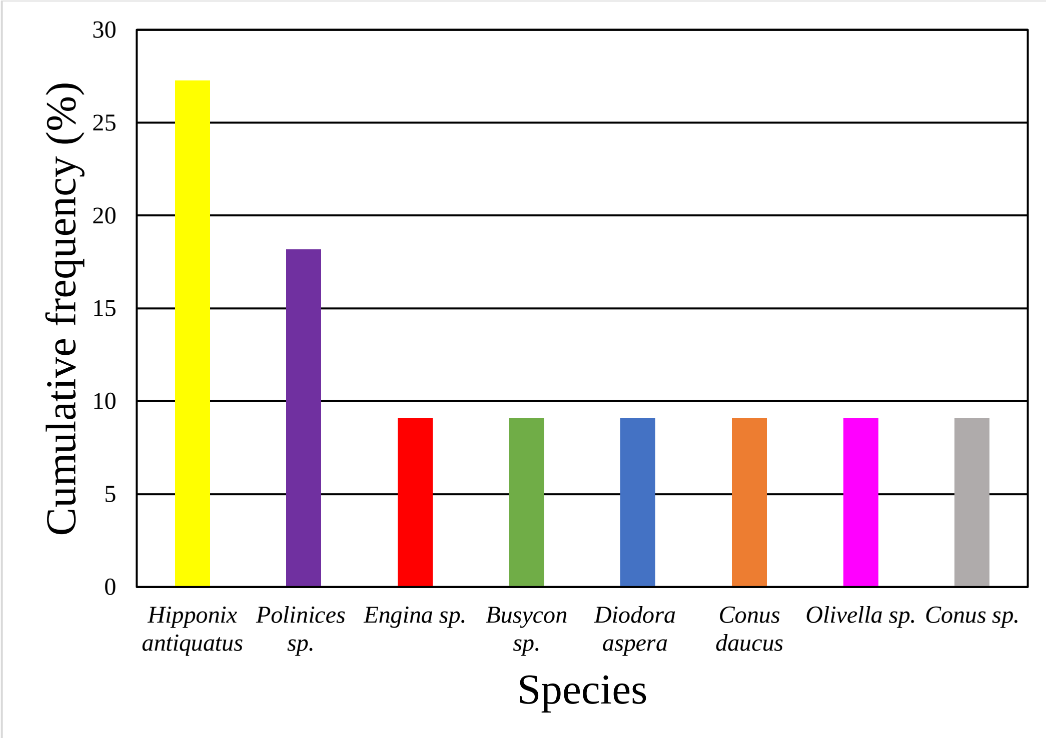

Figure K9. Cumulative frequency (%) of gastropods species at Añasco in October 15, 2016 (n=4).

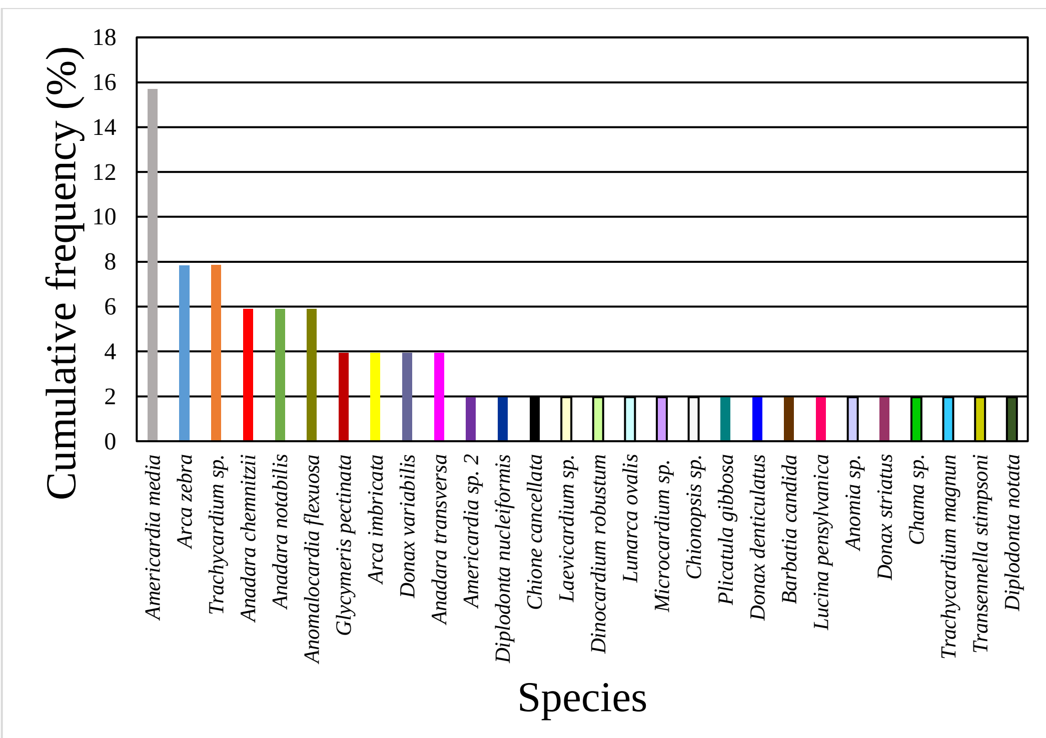

Figure K10. Cumulative frequency (%) of bivalves species at Combate, Cabo Rojo in October 21, 2016 (n=4).

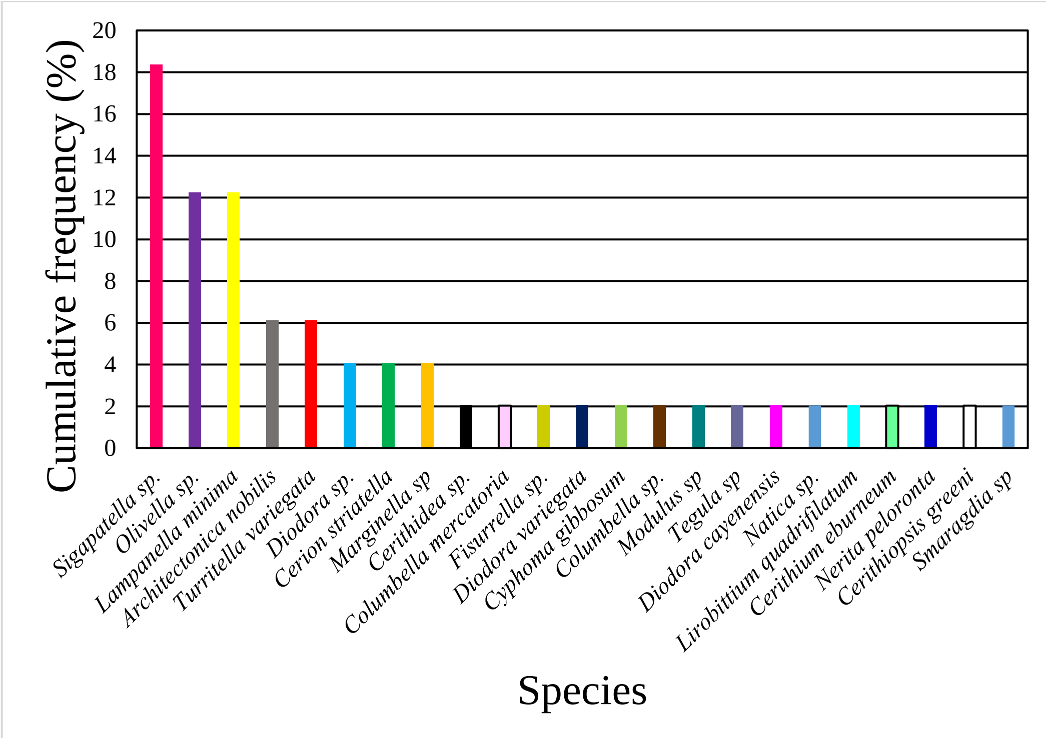

Figure K11. Cumulative frequency (%) of gastropods species at Combate, Cabo Rojo in October 21, 2016 (n=4).

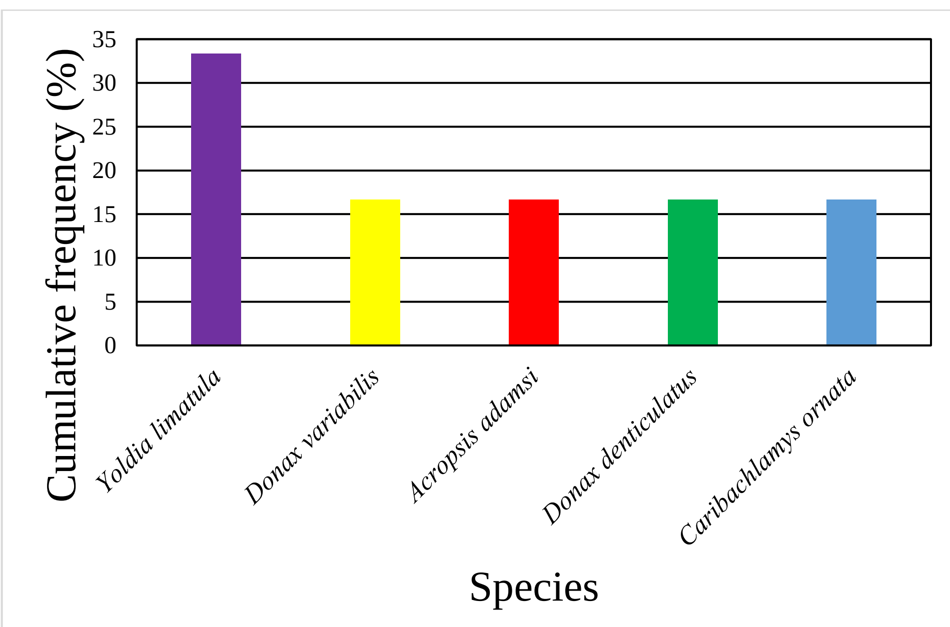

Figure K12. Cumulative frequency (%) of bivalves species at Córcega, Rincón in November 4, 2016 (n=4).

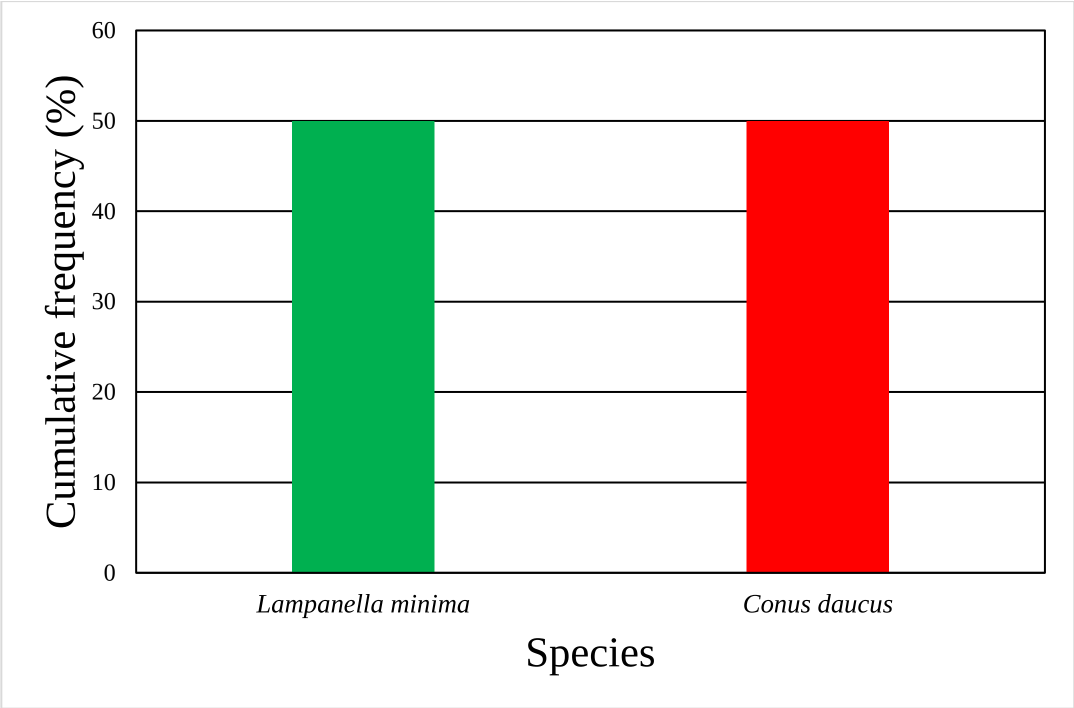

Figure K13. Cumulative frequency (%) of gastropods species at Córcega, Rincón in November 4, 2016 (n=4).

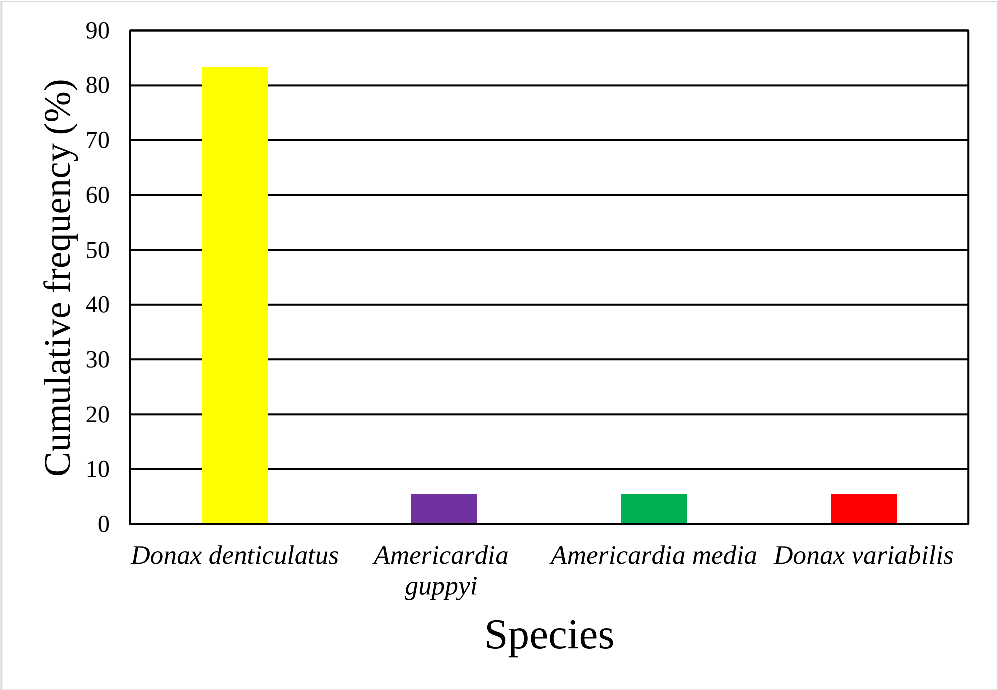

Figure K14. Cumulative frequency (%) of bivalves species at El Maní, Mayagüez in November 18, 2016 (n=4).

Appendix L

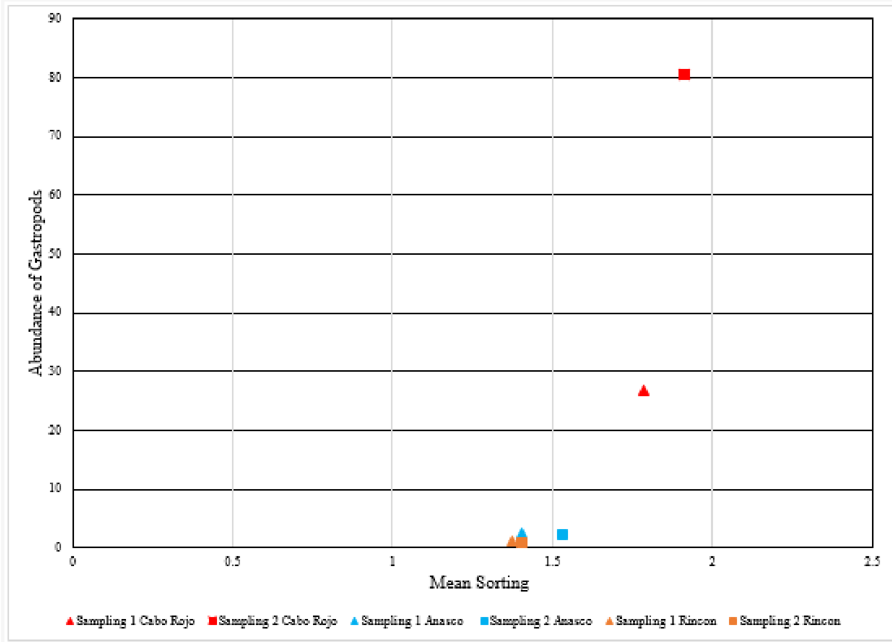

Figure L1. Abundance of gastropods in sand zone during both samplings at all selected beaches.

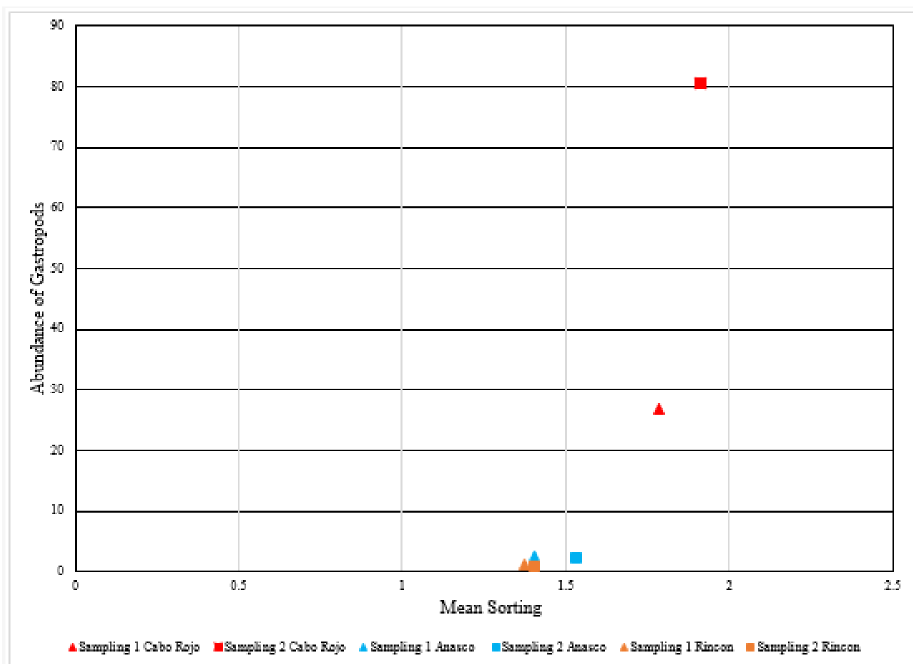

Figure L2. Abundance of gastropods in aquatic zone during both samplings at all selected beaches.

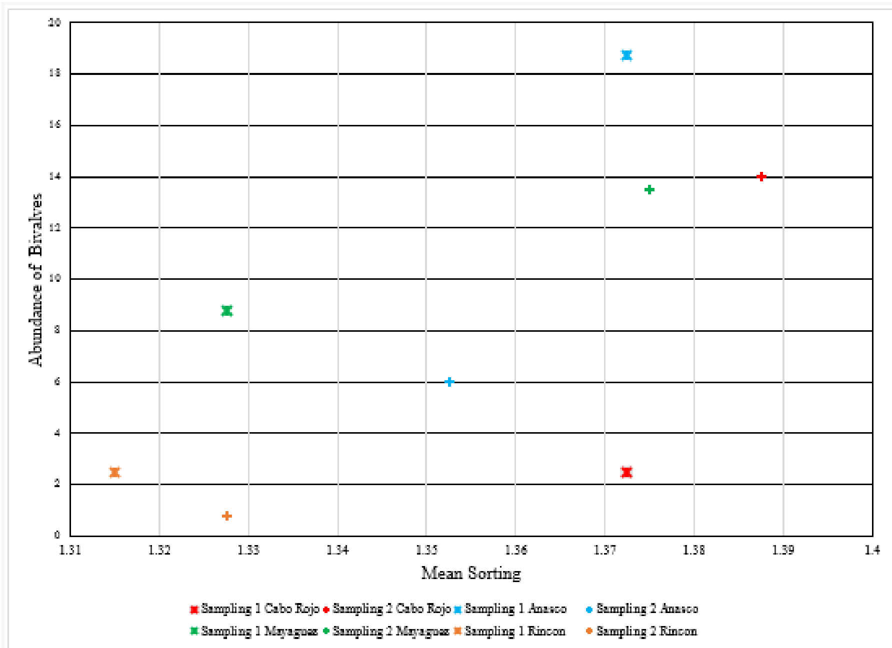

Figure L3. Abundance of bivalves in sand zone during both samplings at all selected beaches.

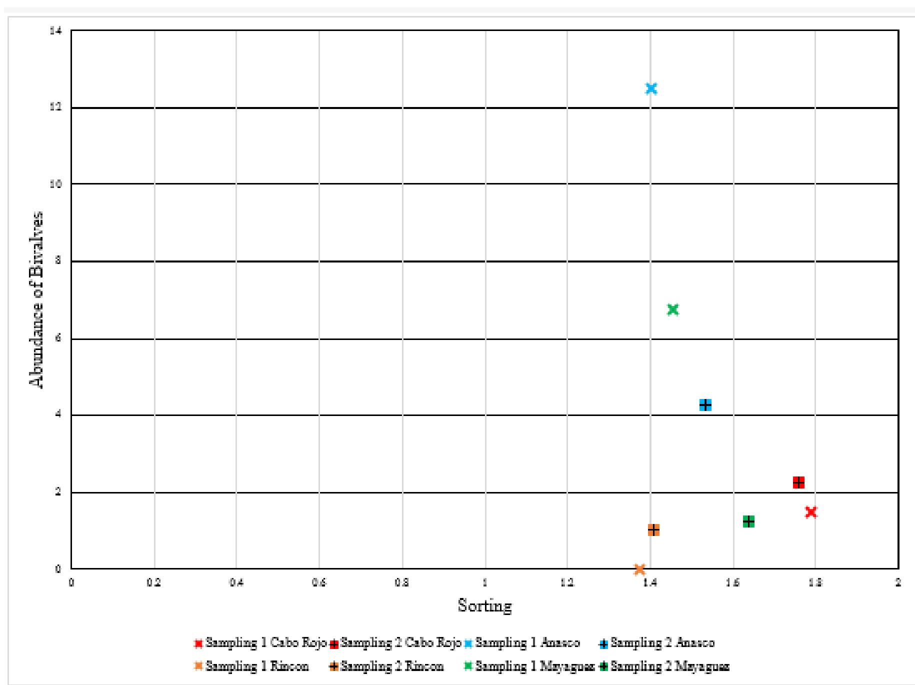

Figure L4. Abundance of bivalves in aquatic zone during both samplings at all selected beaches.

Appendix M

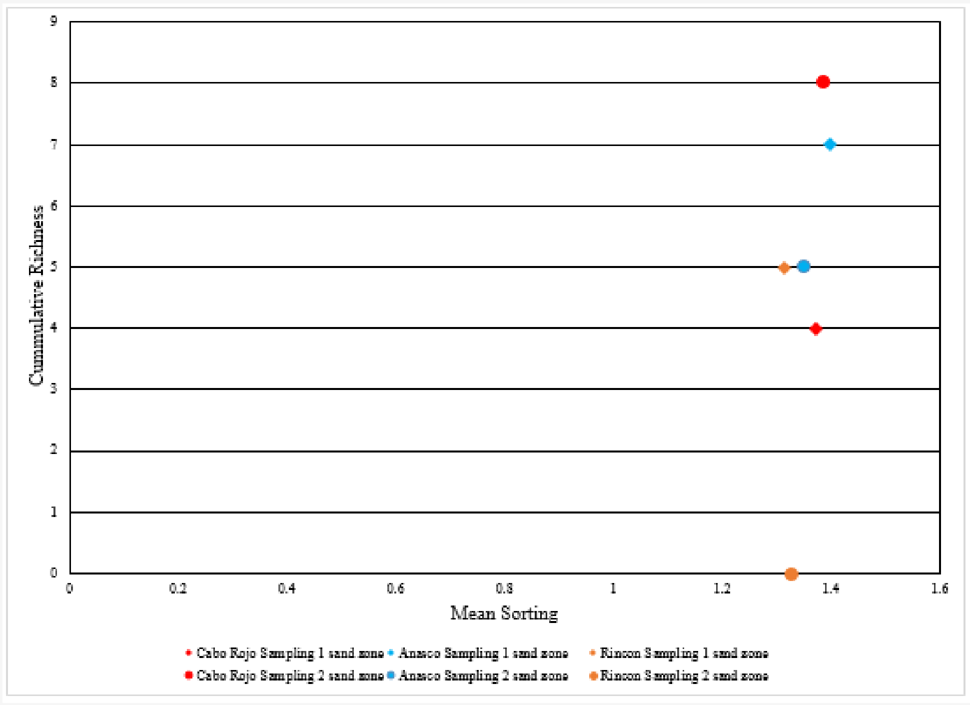

Figure M1. Cumulative richness of gastropods found in the sand zone in both samplings (August/September versus October/November 2016) at selected beaches.

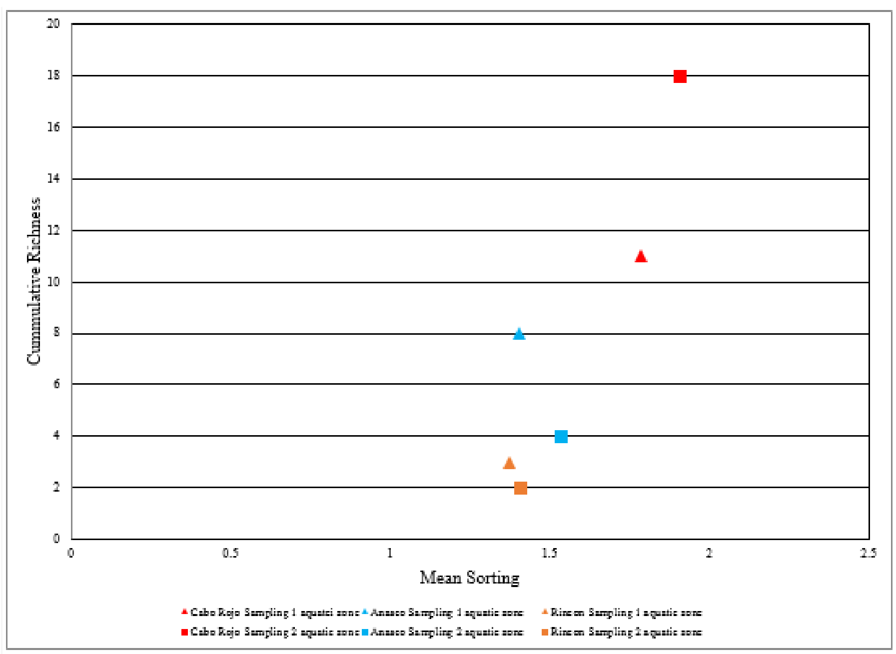

Figure M2. Cumulative richness of gastropods found in the aquatic zone in both samplings (August/September versus October/November 2016) at selected beaches.

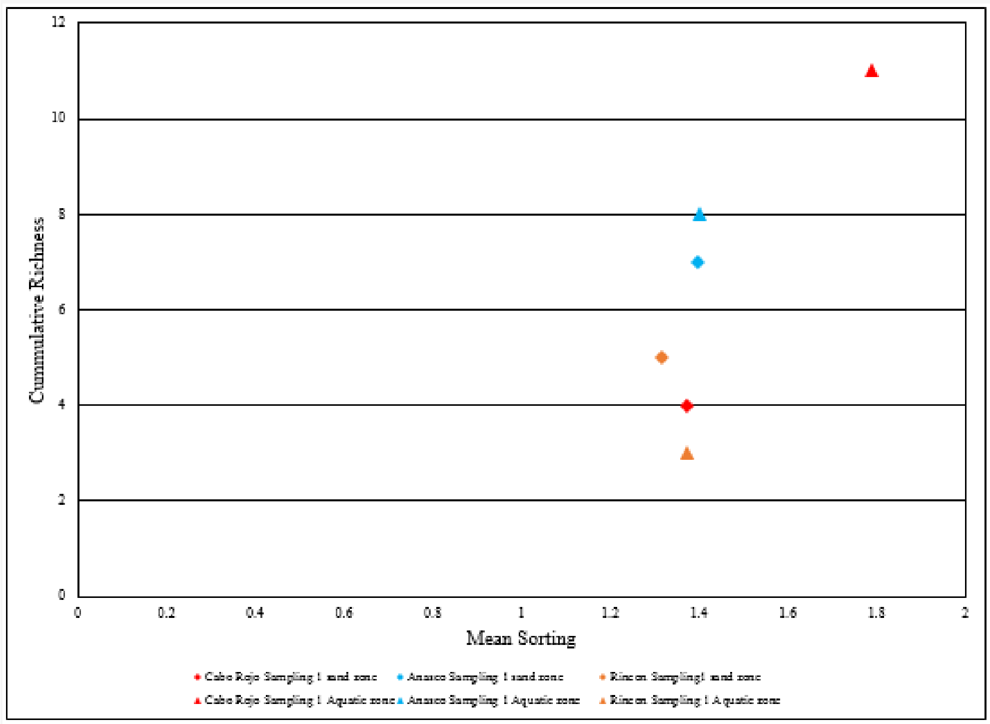

Figure M3. Cumulative richness of gastropods found in both zones (sand versus aquatic) in sampling 1 (August/September 2016) at selected beaches.

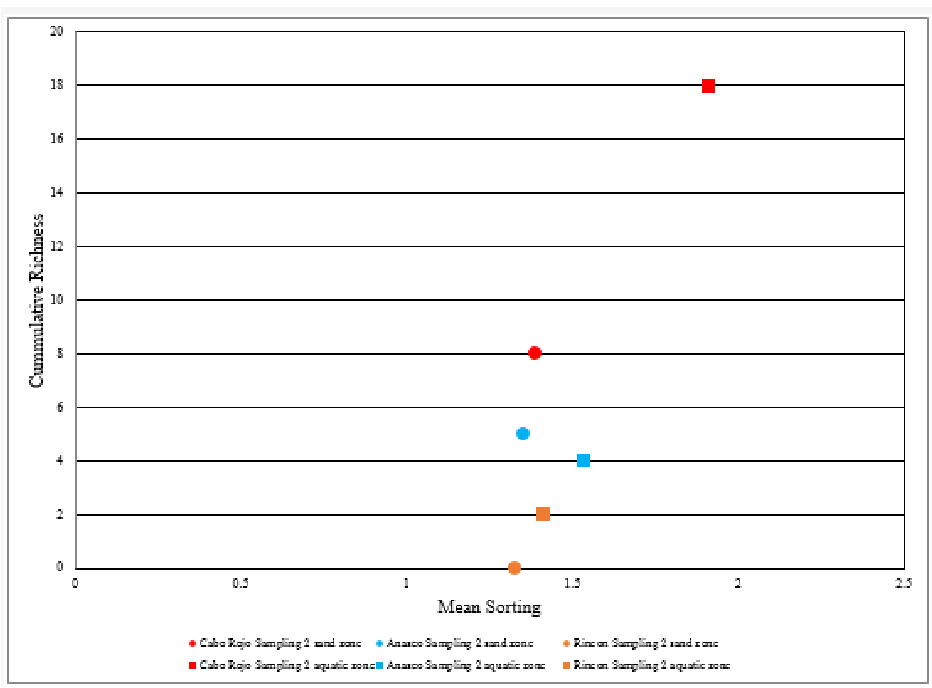

Figure M4. Cumulative richness of gastropods found in both zones (sand versus aquatic) in sampling 2 (October/November 2016) at selected beaches.

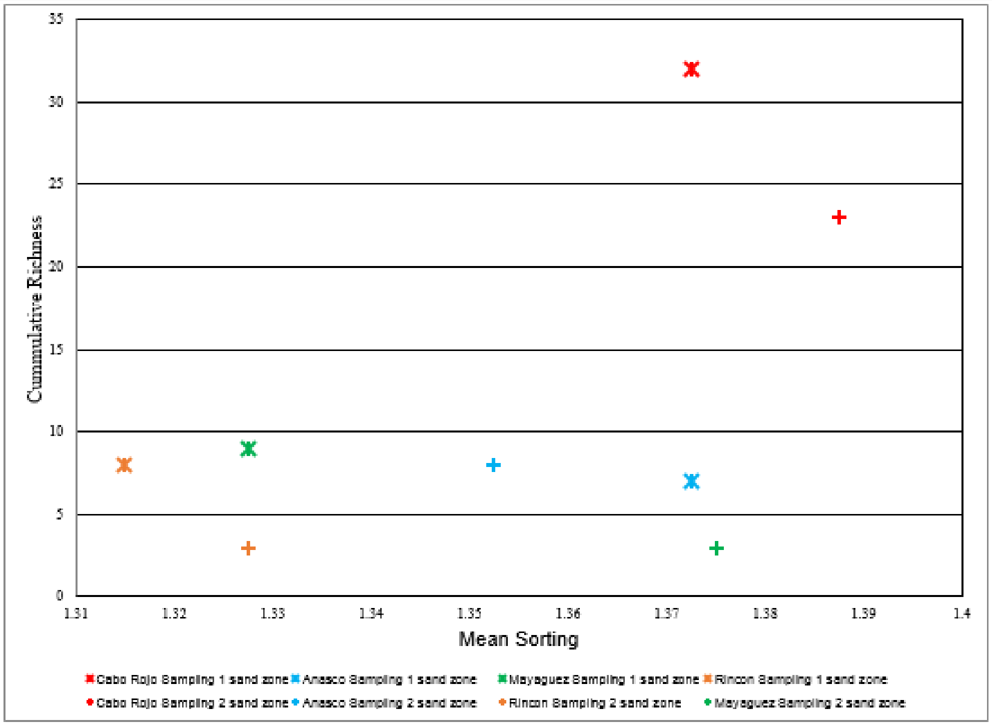

Figure M5. Cumulative richness of bivalves found in the sand zone in both samplings (August/September versus October/November 2016) at selected beaches.

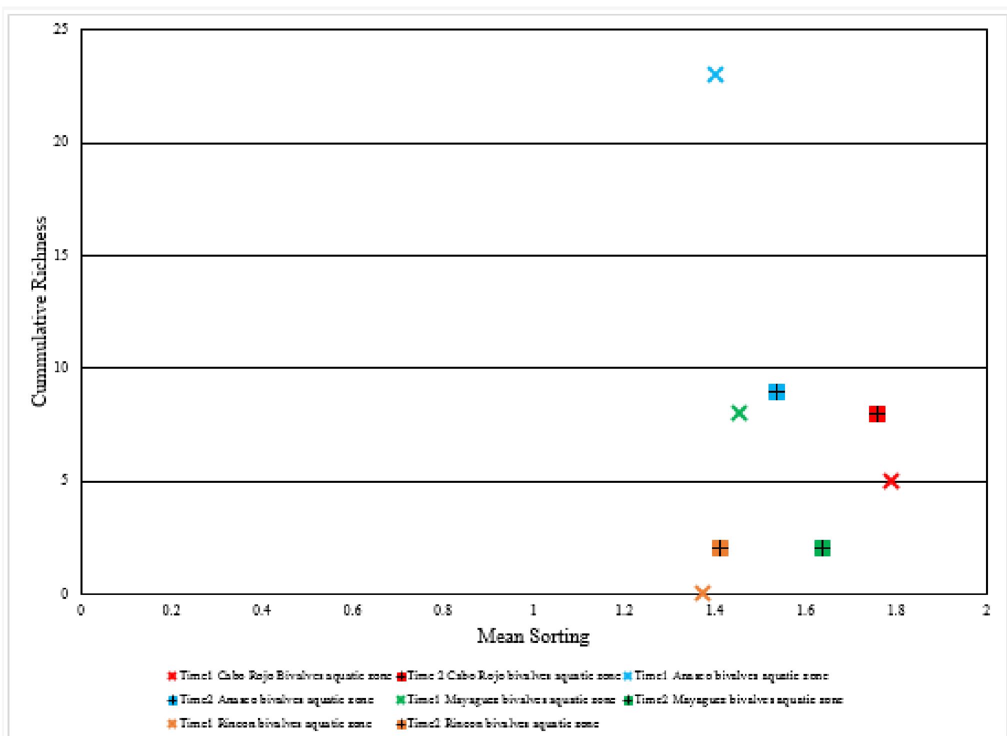

Figure M6. Cumulative richness of bivalves found in the aquatic zone in both samplings (August/September versus October/November 2016) at selected beaches.

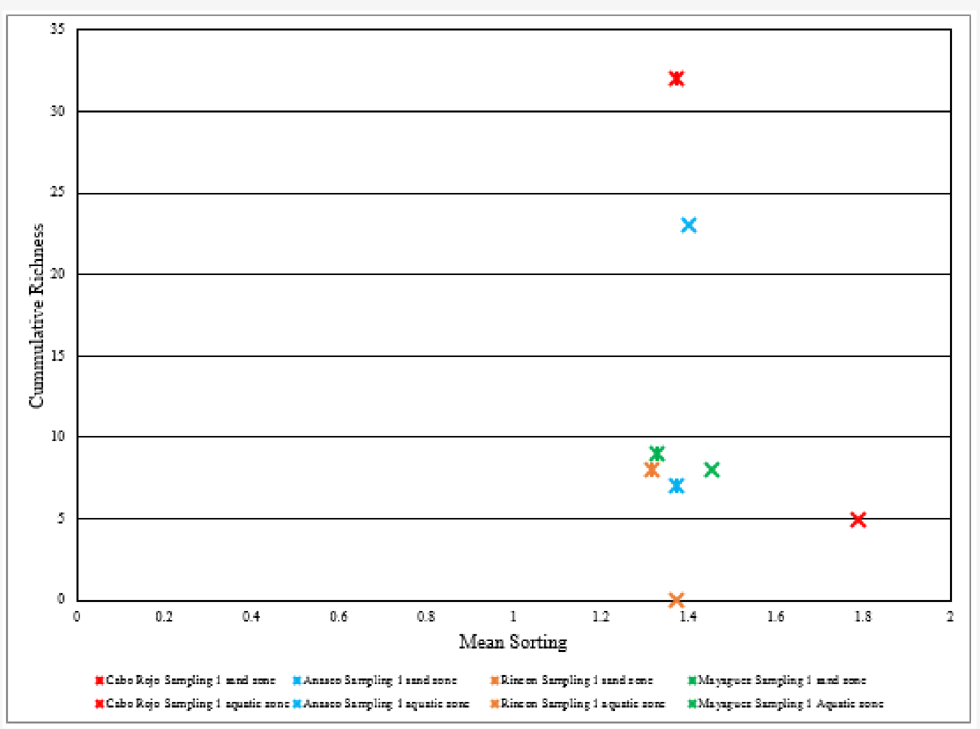

Figure M7. Cumulative richness of bivalves found in both zones (sand versus aquatic) in sampling 1 (August/September 2016) at selected beaches.

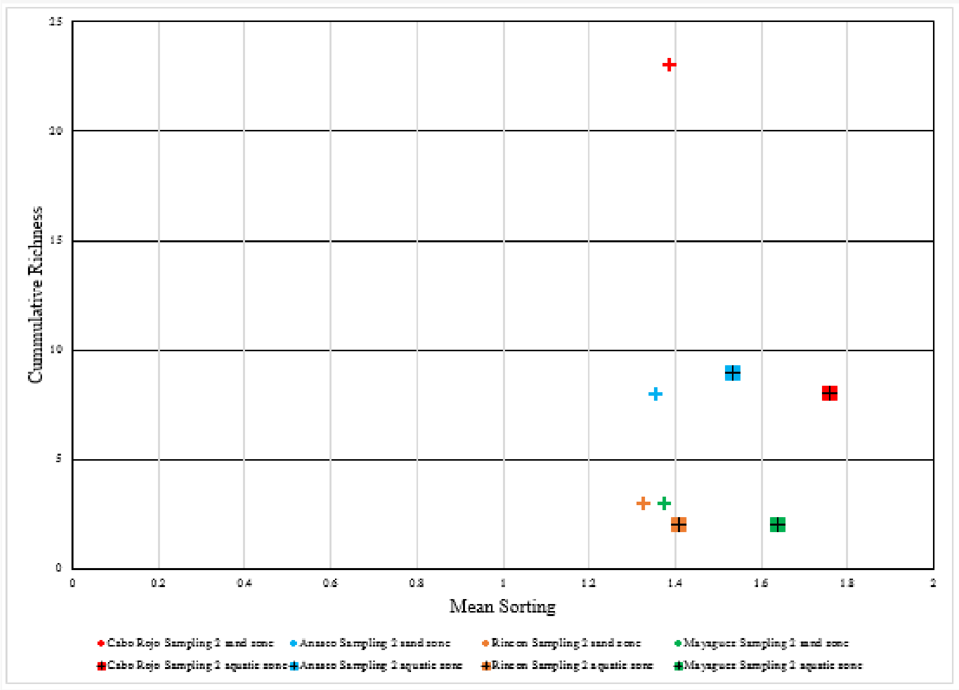

Figure M8. Cumulative richness of bivalves found in both zones (sand versus aquatic)in sampling 2 (October/November 2016) at selected beaches.

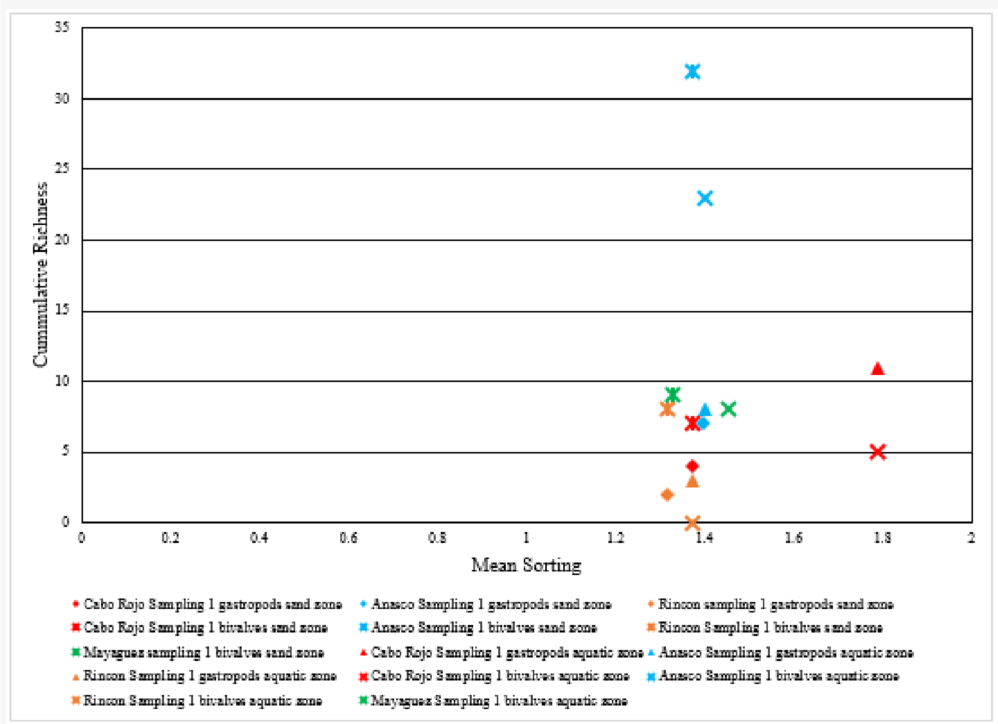

Figure M9. Cumulative richness of shell-mollusks (gastropods and bivalves) found in both zones (sand versus aquatic) in sampling 1 (August/September 2016) at selected beaches.

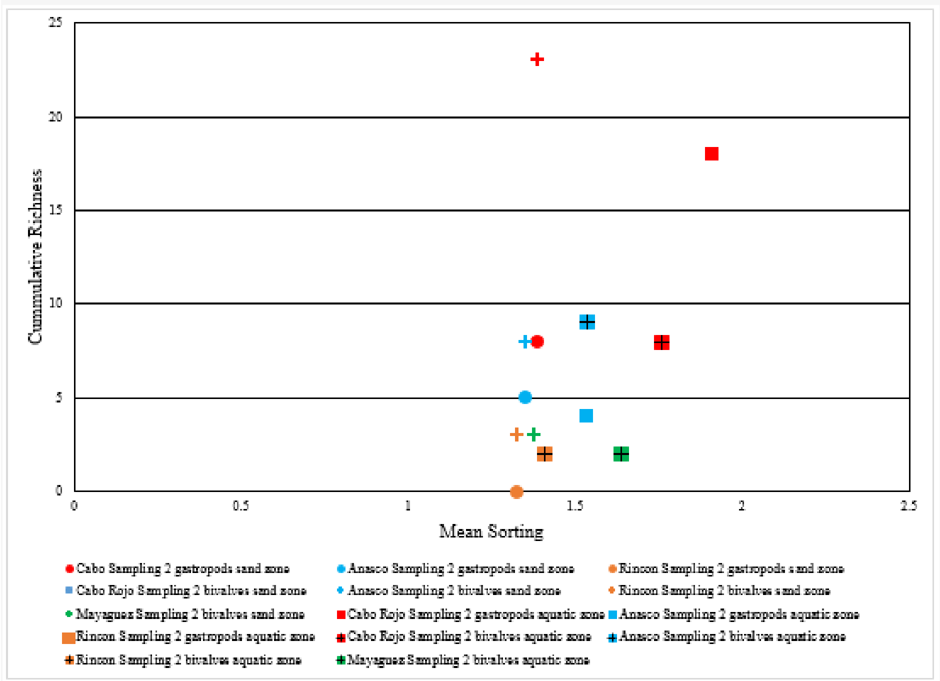

Figure M10. Cumulative richness of shell-mollusks (gastropods and bivalves) found in in both zones (sand versus aquatic) sampling 2 (October/November 2016) at selected beaches.

Appendix N

Table N1. Number of individuals of bivalves that were found at the selected beaches during the different times of the study. Table represents the two means of the samplings versus beach variables and demonstrates the significant differences between all comparisons in the number of bivalves (T-Test).

Classification	Variable	Group 1	Group 2	n(1)	n(2)	Mean (1)	Mean (2)	Mean(1)-Mean(2)	LI(95)	LS(95)	pHomVar	T	p-value	Test
Time*Beach	BivalviaLog(x+1)	{August/September:Añasco}	{August/September:CaboRojo}	24	24	0.66	0.18	0.48	0.31	0.66	0.0029	5.62	<0.0001	Bilateral
Time*Beach	BivalviaLog(x+1)	{August/September:Añasco}	{August/September:Mayagüez}	24	24	0.66	0.22	0.44	0.26	0.62	0.0091	5.01	<0.0001	Bilateral
Time*Beach	BivalviaLog(x+1)	{August/September:Añasco}	{August/September: Rincón}	24	24	0.66	0.12	0.54	0.35	0.72	0.0287	5.98	<0.0001	Bilateral
Time*Beach	BivalviaLog(x+1)	{August/September:Añasco}	{October/November: Añasco}	24	24	0.66	0.35	0.31	0.12	0.50	0.1559	3.27	0.0002	Bilateral
Time*Beach	BivalviaLog(x+1)	{August/September:Añasco}	{October/November:CaboRojo}	24	24	0.66	0.46	0.20	-4.50E-03	0.41	0.6298	1.97	0.0055	Bilateral
Time*Beach	BivalviaLog(x+1)	{August/September:Añasco}	{October/November:Mayagüez}	24	24	0.66	0.4	0.26	0.04	0.47	0.9153	2.43	0.0191	Bilateral
Time*Beach	BivalviaLog(x+1)	{August/September:Añasco}	{October/November: Rincón}	24	24	0.66	0.08	0.58	0.41	0.75	<0.0001	7.05	<0.0001	Bilateral
Time*Beach	BivalviaLog(x+1)	{August/September: CaboRojo}	{October/November: Añasco}	24	24	0.18	0.35	-0.17	-0.31	-0.03	0.1031	-2.51	0.0158	Bilateral
Time*Beach	BivalviaLog(x+1)	{August/September: CaboRojo}	{October/November:CaboRojo}	24	24	0.18	0.46	-0.28	-0.44	-0.12	0.113	-3.54	0.0011	Bilateral
Time*Beach	BivalviaLog(x+1)	{August/September: CaboRojo}	{October/November:Mayagüez}	24	24	0.18	0.4	-0.22	-0.4	-0.05	0.004	-2.66	0.0117	Bilateral
Time*Beach	BivalviaLog(x+1)	{August/September:Mayagüez}	{October/November:CaboRojo}	24	24	0.22	0.46	-0.24	-0.4	-0.07	0.0312	-2.92	0.0057	Bilateral
Time*Beach	BivalviaLog(x+1)	{August/September:Mayagüez}	{October/November:Mayagüez}	24	24	0.22	0.4	-0.18	-0.36	-0.01	0.0121	-2.10	0.0428	Bilateral
Time*Beach	BivalviaLog(x+1)	{August/September:Mayagüez}	{October/November: Rincón}	24	24	0.22	0.08	0.14	0.03	0.25	0.1021	2.62	0.0119	Bilateral
Time*Beach	BivalviaLog(x+1)	{August/September: Rincón}	{October/November: Añasco}	24	24	0.12	0.35	-0.23	-0.37	-0.08	0.4265	-3.07	0.0036	Bilateral
Time*Beach	BivalviaLog(x+1)	{August/September: Rincón}	{October/November:CaboRojo}	24	24	0.12	0.46	-0.34	-0.50	-0.17	0.0845	-4.00	0.0002	Bilateral
Time*Beach	BivalviaLog(x+1)	{August/September: Rincón}	{October/November:Mayagüez}	24	24	0.12	0.4	-0.28	-0.46	-0.10	0.0369	-3.14	0.0031	Bilateral
Time*Beach	BivalviaLog(x+1)	{October/November: Añasco}	{October/November: Rincón}	24	24	0.35	0.08	0.27	0.14	0.40	0.0049	4.18	0.0002	Bilateral
Time*Beach	BivalviaLog(x+1)	{October/November:CaboRojo}	{October/November: Rincón}	24	24	0.46	0.08	0.38	0.22	0.53	0.003	5.00	<0.0001	Bilateral
Time*Beach	BivalviaLog(x+1)	{October/November:Mayagüez}	{October/November: Rincón}	24	24	0.40	0.08	0.32	0.16	0.48	0.0001	3.97	0.0004	Bilateral

Table N2. Number of individuals of bivalves found at the selected beaches at both samplings and both zones. There were differences in the number of bivalves, between group 1 (August/September and sand zone) and group 2 (October/November and aquatic zone) (T-Test).

Classification	Variable	Group 1	Group 2	n(1)	n(2)	Mean(1)	Mean(2)	Mean(1)-Mean(2)	LI(95)	LS(95)	pHomVar	T	p-value	Test
Time*Zone	BivalviaLog(x+1)	{August/September: aquatic}	{August/September: sand}	48	48	0.24	0.35	-0.11	-0.24	0.03	0.7655	-1.58	0.1176	Bilateral
Time*Zone	BivalviaLog(x+1)	{August/September: aquatic}	{October/November:aquatic}	48	48	0.24	0.16	0.08	-0.04	0.2	0.0466	1.37	0.1741	Bilateral

Time*Zone	BivalviaLog(x+1)	{August/September: aquatic}	{October/November:sand}	48	48	0.24	0.49	-0.25	-0.37	-0.11	0.8041	-3.71	0.0003	Bilateral
Time*Zone	BivalviaLog(x+1)	{August/September: sand}	{October/November:aquatic}	48	48	0.35	0.16	0.19	0.07	0.31	0.0226	3.11	0.0025	Bilateral
Time*Zone	BivalviaLog(x+1)	{August/September: sand}	{October/November:sand}	48	48	0.35	0.49	-0.14	-0.27	-2.50E-03	0.585	-2.02	0.0459	Bilateral
Time*Zone	BivalviaLog(x+1)	{October/November:aquatic}	{October/November:sand}	48	48	0.16	0.49	-0.33	-0.44	-0.21	0.0808	-5.64	<0.0001	Bilateral

Table N3. There were no significant differences between the two groups with variables time and transect in all selected beaches (T-Test).

Classification	Variable	Group 1	Group 2	n(1)	n(2)	Mean(1)	Mean(2)	Mean(1)-Mean(2)	LI(95)	LS(95)	pHomVar	T	p-value	Test
Time*Transect	BivalviaLog(x+1)	{August/September:T1}	{August/September:T2}	24	24	0.27	0.28	-0.01	-0.19	0.18	0.1754	-0.07	0.9484	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T1}	{August/September:T3}	24	24	0.27	0.36	-0.09	-0.29	0.12	0.0314	-0.83	0.4139	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T1}	{August/September:T4}	24	24	0.27	0.28	-4.50E-03	-0.17	0.16	0.669	-0.06	0.9561	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T1}	{October/November:T1}	24	24	0.27	0.26	0.01	-0.16	0.18	0.3999	0.16	0.8736	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T1}	{October/November:T2}	24	24	0.27	0.31	-0.04	-0.21	0.15	0.2253	-0.38	0.7076	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T1}	{October/November:T3}	24	24	0.27	0.38	-0.11	-0.29	0.07	0.1769	-1.19	0.2391	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T1}	{October/November:T4}	24	24	0.27	0.35	-0.08	-0.23	0.08	0.8561	-0.97	0.3358	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T2}	{August/September:T3}	24	24	0.28	0.36	-0.08	-0.31	0.15	0.4108	-0.69	0.4907	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T2}	{August/September:T4}	24	24	0.28	0.28	-1.40E-03	-0.19	0.19	0.3506	0.02	0.9878	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T2}	{October/November:T1}	24	24	0.28	0.26	0.02	-0.18	0.22	0.6033	0.2	0.8425	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T2}	{October/November:T2}	24	24	0.28	0.31	-0.03	-0.23	0.18	0.8848	-0.27	0.7855	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T2}	{October/November:T3}	24	24	0.28	0.38	-0.10	-0.31	0.10	0.9964	-1.00	0.3242	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T2}	{October/November:T4}	24	24	0.28	0.35	-0.07	-0.26	0.11	0.2392	-0.77	0.4477	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T3}	{August/September:T4}	24	24	0.36	0.28	0.08	-0.13	0.29	0.0816	0.76	0.4507	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T3}	{October/November:T1}	24	24	0.36	0.26	0.10	-0.12	0.32	0.1816	0.91	0.3701	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T3}	{October/November:T2}	24	24	0.36	0.31	0.05	-0.17	0.27	0.334	0.45	0.6513	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T3}	{October/November:T3}	24	24	0.36	0.38	-0.02	-0.25	0.20	0.4083	-0.21	0.8334	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T3}	{October/November:T4}	24	24	0.36	0.35	0.01	-0.20	0.22	0.0478	0.08	0.9393	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T4}	{October/November:T1}	24	24	0.28	0.26	0.02	-0.16	0.20	0.6775	0.20	0.8389	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T4}	{October/November:T2}	24	24	0.28	0.31	-0.03	-0.21	0.16	0.4297	-0.32	0.7536	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T4}	{October/November:T3}	24	24	0.28	0.38	-0.10	-0.29	0.09	0.353	-1.10	0.2075	Bilateral
Time*Transect	BivalviaLog(x+1)	{August/September:T4}	{October/November:T4}	24	24	0.28	0.35	-0.07	-0.24	0.09	0.8054	-0.88	0.3086	Bilateral
Time*Transect	BivalviaLog(x+1)	{October/November:T1}	{October/November:T2}	24	24	0.26	0.31	-0.05	-0.24	0.15	0.7076	-0.49	0.6025	Bilateral
Time*Transect	BivalviaLog(x+1)	{October/November:T1}	{October/November:T3}	24	24	0.26	0.38	-0.12	-0.32	0.07	0.6065	-1.25	0.2178	Bilateral
Time*Transect	BivalviaLog(x+1)	{October/November:T1}	{October/November:T4}	24	24	0.26	0.35	-0.09	-0.26	0.08	0.5083	-1.04	0.3022	Bilateral
Time*Transect	BivalviaLog(x+1)	{October/November:T2}	{October/November:T3}	24	24	0.31	0.38	-0.07	-0.28	0.13	0.8884	-0.74	0.4645	Bilateral
Time*Transect	BivalviaLog(x+1)	{October/November:T2}	{October/November:T4}	24	24	0.31	0.35	-0.04	-0.22	0.14	0.3012	-0.47	0.6038	Bilateral
Time*Transect	BivalviaLog(x+1)	{October/November:T3}	{October/November:T4}	24	24	0.38	0.35	0.03	-0.15	0.22	0.2411	0.35	0.7313	Bilateral

Table N4. Significant differences in the number of bivalves per beach (T-Test).

Classification	Variable	Group 1	Group 2	n(1)	n(2)	Mean(1)	Mean(2)	Mean(1)-Mean(2)	LI(95)	LS(95)	pHomVar	T	p-value	Test
Beach*Transect	BivalviaLog(x+1)	{Añasco:T1}	{Añasco:T3}	12	12	0.32	0.73	-0.41	-0.7	-0.12	0.1361	-2.94	0.0076	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T1}	{Rincón:T3}	12	12	0.32	0.03	0.29	0.12	0.46	0.0011	3.72	0.0026	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T1}	{Rincón:T4}	12	12	9.32	0.12	-4.50E-03	0.02	0.39	0.2203	2.25	0.0035	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T2}	{Cabo Rojo:T2}	12	12	0.52	0.21	0.31	0.04	0.58	0.4931	2.38	0.0261	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T2}	{Rincón:T1}	12	12	0.52	0.13	0.39	0.12	0.64	0.3303	3.07	0.0056	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T2}	{Rincón:T2}	12	12	0.52	0.14	0.38	0.13	0.62	0.1462	3.17	0.0045	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T2}	{Rincón:T3}	12	12	0.52	0.03	0.49	0.27	0.72	0.0001	4.75	0.0005	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T2}	{Rincón:T4}	12	12	0.52	0.12	0.4	0.16	0.64	0.0328	3.57	0.0024	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T3}	{Cabo Rojo:T1}	12	12	0.73	0.28	1.40E-03	0.13	0.76	0.5202	2.9	0.0083	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T3}	{Cabo Rojo:T2}	12	12	0.73	0.21	0.52	0.22	0.82	0.2228	2.62	0.0015	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T3}	{Cabo Rojo:T3}	12	12	0.73	0.42	0.31	0.01	0.62	0.3351	2.11	0.0462	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T3}	{Cabo Rojo:T4}	12	12	0.73	0.36	0.37	0.06	0.67	0.3044	2.49	0.0029	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T3}	{Mayagüez:T1}	12	12	0.73	0.33	0.4	0.1	0.71	0.2914	2.74	0.0119	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T3}	{Mayagüez:T2}	12	12	0.73	0.3	0.43	0.07	0.78	0.9474	2.51	0.0199	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T3}	{Mayagüez:T3}	12	12	0.73	0.3	0.43	0.12	0.73	0.3095	2.9	0.0083	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T3}	{Mayagüez:T4}	12	12	0.73	0.31	0.42	0.13	0.70	0.0654	3.06	0.0058	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T3}	{Rincón:T1}	12	12	0.73	0.13	0.60	0.31	0.89	0.1337	4.25	0.0003	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T3}	{Rincón:T2}	12	12	0.73	0.14	0.59	0.30	0.87	0.0496	4.37	0.0004	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T3}	{Rincón:T3}	12	12	0.73	0.03	0.70	0.44	0.97	<0.001	5.80	0.0001	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T3}	{Rincón:T4}	12	12	0.73	0.12	0.61	0.34	0.89	0.0089	4.75	0.0003	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T4}	{Rincón:T1}	12	12	0.46	0.13	0.33	0.08	0.57	0.4837	2.75	0.0117	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T4}	{Rincón:T2}	12	12	0.46	0.14	0.32	0.09	0.55	0.2354	2.85	0.0094	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T4}	{Rincón:T3}	12	12	0.46	0.03	0.43	0.23	0.64	0.0001	4.54	0.0007	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Añasco:T4}	{Rincón:T4}	12	12	0.46	0.12	0.34	0.13	0.56	0.0599	3.27	0.0035	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Cabo Rojo:T1}	{Rincón:T3}	12	12	0.28	0.03	0.25	0.04	0.48	0.0001	2.57	0.0246	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Cabo Rojo:T3}	{Rincón:T1}	12	12	0.42	0.13	0.29	0.04	0.52	0.5798	2.46	0.0222	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Cabo Rojo:T3}	{Rincón:T2}	12	12	0.42	0.14	0.28	0.05	0.50	0.2971	2.55	0.0184	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Cabo Rojo:T3}	{Rincón:T3}	12	12	0.42	0.03	0.39	0.19	0.59	0.0002	4.28	0.0009	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Cabo Rojo:T3}	{Rincón:T4}	12	12	0.42	0.12	0.30	0.09	0.51	0.0812	2.97	0.0071	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Cabo Rojo:T4}	{Rincón:T2}	12	12	0.36	0.14	0.22	1.30E03	0.45	0.3273	2.09	0.0488	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Cabo Rojo:T4}	{Rincón:T3}	12	12	0.36	0.03	0.33	0.14	0.53	0.0003	3.77	0.0023	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Cabo Rojo:T4}	{Rincón:T4}	12	12	0.36	0.12	0.24	0.04	0.46	0.0923	2.48	0.0211	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Mayagüez:T1}	{Rincón:T3}	12	12	0.33	0.03	0.30	0.11	0.50	0.0003	3.40	0.0048	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Mayagüez:T1}	{Rincón:T4}	12	12	0.33	0.12	0.21	0.01	0.42	0.0976	2.14	0.0437	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Mayagüez:T2}	{Rincón:T3}	12	12	0.3	0.03	0.27	0.01	0.55	<0.0001	2.24	0.0446	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Mayagüez:T3}	{Rincón:T3}	12	12	0.3	0.03	0.27	0.08	0.47	0.0003	3.08	0.0088	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Mayagüez:T4}	{Rincón:T3}	12	12	0.31	0.03	0.28	0.14	0.44	0.0032	4.06	0.0012	Bilateral
Beach*Transect	BivalviaLog(x+1)	{Mayagüez:T4}	{Rincón:T4}	12	12	0.31	0.12	0.19	0.03	0.37	0.3897	2.37	0.0268	Bilateral

Table N5. Significant difference between the two groups (beach versus sand and aquatic zone) between variables zone and beach (T-Test).

Classification	Variable	Group 1	Group 2	n(1)	n(2)	Mean(1)	Mean(2)	Mean(1)-Mean(2)	LI(95)	LS(95)	pHomVar	T	p-value	Test
Zone*Beach	BivalviaLog(x+1)	{aquatic:Añasco}	{aquatic:CaboRojo}	24	24	0.40	0.17	0.23	0.04	0.42	0.0008	2.48	0.0184	Bilateral
Zone*Beach	BivalviaLog(x+1)	{aquatic:Añasco}	{aquatic:Mayagüez}	24	24	0.40	0.17	0.22	0.03	0.42	0.0057	2.37	0.0234	Bilateral
Zone*Beach	BivalviaLog(x+1)	{aquatic:Añasco}	{aquatic:Rincón}	24	24	0.40	0.07	0.32	0.14	0.51	0.0003	3.53	0.0013	Bilateral
Zone*Beach	BivalviaLog(x+1)	{aquatic:Añasco}	{sand:Añasco}	24	24	0.40	0.62	-0.22	-0.42	-0.02	0.0627	-2.20	0.0326	Bilateral
Zone*Beach	BivalviaLog(x+1)	{aquatic:Añasco}	{sand:Rincón}	24	24	0.40	0.13	0.27	0.07	0.45	0.0019	2.82	0.0078	Bilateral
Zone*Beach	BivalviaLog(x+1)	{aquatic:CaboRojo}	{sand:Añasco}	24	24	0.17	0.62	-0.45	-0.59	-0.31	0.1113	-6.55	<0.0001	Bilateral
Zone*Beach	BivalviaLog(x+1)	{aquatic:CaboRojo}	{sand:Cabo Rojo}	24	24	0.17	0.47	-0.30	-0.46	-0.14	0.0158	-3.88	0.0004	Bilateral
Zone*Beach	BivalviaLog(x+1)	{aquatic:CaboRojo}	{sand:Mayagüez}	24	24	0.17	0.45	-0.28	-0.44	-0.13	0.019	-3.70	0.0007	Bilateral
Zone*Beach	BivalviaLog(x+1)	{aquatic:Mayagüez}	{sand:Añasco}	24	24	0.17	0.62	-0.44	-0.59	-0.3	0.3394	-6.17	<0.0001	Bilateral
Zone*Beach	BivalviaLog(x+1)	{aquatic:Mayagüez}	{sand:Cabo Rojo}	24	24	0.17	0.47	-0.30	-0.46	-0.13	0.0726	-3.68	0.0006	Bilateral
Zone*Beach	BivalviaLog(x+1)	{aquatic:Mayagüez}	{sand:Mayagüez}	24	24	0.17	0.45	-0.28	-0.44	-0.12	0.0845	-3.51	0.001	Bilateral
Zone*Beach	BivalviaLog(x+1)	{aquatic:Rincón}	{sand:Añasco}	24	24	0.07	0.62	-0.55	-0.68	-0.41	0.0583	-8.08	<0.0001	Bilateral
Zone*Beach	BivalviaLog(x+1)	{aquatic:Rincón}	{sand:Cabo Rojo}	24	24	0.07	0.47	-0.40	-0.55	-0.24	0.0069	-5.16	<0.0001	Bilateral
Zone*Beach	BivalviaLog(x+1)	{aquatic:Rincón}	{sand:Mayagüez}	24	24	0.07	0.45	-0.38	-0.53	-0.22	0.0084	-5.00	<0.0001	Bilateral
Zone*Beach	BivalviaLog(x+1)	{sand:Añasco}	{sand:Rincón}	24	24	0.62	0.13	0.49	0.34	0.62	0.1875	6.91	<0.0001	Bilateral
Zone*Beach	BivalviaLog(x+1)	{sand:Cabo Rojo}	{sand:Rincón}	24	24	0.47	0.13	0.34	0.18	0.50	0.0317	4.26	0.0001	Bilateral
Zone*Beach	BivalviaLog(x+1)	{sand:Mayagüez}	{sand:Rincón}	24	24	0.45	0.13	0.32	0.16	0.48	0.0376	4.09	0.0002	Bilateral

Table N6. Significant difference in bivalves between variables transects and zone (T-Test).

Classification	Variable	Group 1	Group 2	n(1)	n(2)	Mean(1)	Mean(2)	Mean(1)-Mean(2)	LI(95)	LS(95)	pHomVar	T	p-value	Test
Transect*Zone	BivalviaLog(x+1)	{T1:aquatic}	{T1:sand}	24	24	0.14	0.39	-0.25	-0.40	-0.10	0.1967	-3.27	0.0021	Bilateral
Transect*Zone	BivalviaLog(x+1)	{T1:aquatic}	{T2:sand}	24	24	0.14	0.44	-0.30	-0.47	-0.12	0.0322	-3.44	0.0014	Bilateral
Transect*Zone	BivalviaLog(x+1)	{T1:aquatic}	{T3:sand}	24	24	0.14	0.48	-0.34	-0.53	-0.15	0.0073	-3.57	0.0001	Bilateral
Transect*Zone	BivalviaLog(x+1)	{T1:aquatic}	{T4:sand}	24	24	0.14	0.36	-0.22	-0.36	-0.08	0.5038	-3.11	0.0032	Bilateral
Transect*Zone	BivalviaLog(x+1)	{T1:sand}	{T2:aquatic}	24	24	0.39	0.15	0.24	0.08	0.41	0.6258	2.98	0.0045	Bilateral
Transect*Zone	BivalviaLog(x+1)	{T2:aquatic}	{T2:sand}	24	24	0.15	0.44	-0.29	-0.48	-0.11	0.1744	-3.20	0.0025	Bilateral
Transect*Zone	BivalviaLog(x+1)	{T2:aquatic}	{T3:sand}	24	24	0.15	0.48	-0.34	-0.53	-0.14	0.0552	-3.38	0.0015	Bilateral
Transect*Zone	BivalviaLog(x+1)	{T2:aquatic}	{T4:sand}	24	24	0.15	0.36	-0.21	-0.37	-0.06	0.8876	-2.81	0.0073	Bilateral
Transect*Zone	BivalviaLog(x+1)	{T3:aquatic}	{T3:sand}	24	24	0.26	0.48	-0.22	-0.44	-0.01	0.4008	-2.08	0.0043	Bilateral

Transect*Zone	BivalviaLog(x+1)	{T3:sand}	{T4:aquatic}	24	24	0.48	0.27	0.22	0.01	0.42	0.1711	2.09	0.0423	Bilateral

Table N7. Number of individuals of gastropods found at the selected beaches during both samplings. The variables of time and beach demonstrated a difference in their means. As a result, the number of gastropods is different. (T-Test).

Classification	Variable	Group 1	Group 2	n(1)	n(2)	Mean (1)	Mean (2)	Mean(1)-Mean(2)	LI(95)	LS(95)	pHomVar	T	p-value	Test
Time*Beach	Gastropoda log(x+1)	{August/September:Añasco}	{August/September:Cabo Rojo}	24	24	0.18	0.48	-0.30	-0.53	-0.06	0.0002	-2.57	0.0152	Bilateral
Time*Beach	Gastropoda log(x+1)	{August/September:Añasco}	{August/September:Cabo Rojo}	24	24	0.18	0.62	-0.44	-0.72	-0.16	<0.0001	-3.18	0.0035	Bilateral
Time*Beach	Gastropoda log(x+1)	{August/September:Añasco}	{August/September:Rincón}	24	24	0.18	0.03	0.15	0.06	0.26	<0.0001	3.21	0.0031	Bilateral
Time*Beach	Gastropoda log(x+1)	{August/September:Cabo Rojo}	{August/September:Rincón}	24	24	0.48	0.10	0.38	0.15	0.61	<0.0001	3.36	0.0021	Bilateral
Time*Beach	Gastropoda log(x+1)	{August/September:Cabo Rojo}	{August/September:Añasco}	24	24	0.48	0.14	0.34	0.11	0.57	<0.0001	2.99	0.0056	Bilateral
Time*Beach	Gastropoda log(x+1)	{August/September:Cabo Rojo}	{August/September:Rincón}	24	24	0.48	0.03	0.45	0.23	0.67	<0.0001	4.23	0.0003	Bilateral
Time*Beach	Gastropoda log(x+1)	{August/September:Rincón}	{October/November:Cabo Rojo}	24	24	0.10	0.62	-0.52	-0.80	-0.24	<0.0001	-3.84	0.0007	Bilateral
Time*Beach	Gastropoda log(x+1)	{October/November:Añasco}	{October/November:Cabo Rojo}	24	24	0.14	0.62	-0.48	-0.76	-0.20	<0.0001	-3.53	0.0015	Bilateral
Time*Beach	Gastropoda log(x+1)	{October/November:Añasco}	{October/November:Rincón	24	24	0.14	0.03	0.11	0.03	0.20	0.0002	2.63	0.0013	Bilateral
Time*Beach	Gastropoda log(x+1)	{October/November:Cabo Rojo}	{October/November:Rincón	24	24	0.62	0.03	0.59	0.32	0.86	<0.0001	4.54	0.0001	Bilateral

Table N8. The only significant difference between group 1 (August/September versus T1) and group 2 (October/November versus T2) (T-Test).

Classification	Variable	Group 1	Group 2	n(1)	n(2)	Mean(1)	Mean(2)	Mean(1)-Mean(2)	LI(95)	LS(95)	pHomVar	T	p-value	Test
Time*Transect	Gastropodalog(x+1)	{August/September:T1}	{August/September:T2}	18	18	0.43	0.14	0.29	-0.02	0.59	<0.0001	1.97	0.0626	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T1}	{August/September:T3}	18	18	0.43	0.20	0.23	-0.09	0.56	0.0074	1.51	0.1441	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T1}	{August/September:T4}	18	18	0.43	0.24	0.19	-0.12	0.51	0.0017	1.29	0.2081	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T1}	{October/November:T1}	18	18	0.43	0.16	0.27	-0.05	0.60	0.0196	1.74	0.0932	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T1}	{October/November:T2}	18	18	0.43	0.13	0.30	-0.01	0.60	<0.0001	2.05	0.0540	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T1}	{October/November:T3}	18	18	0.43	0.30	0.13	-0.23	0.50	0.4369	0.74	0.4647	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T1}	{October/November:T4}	18	18	0.43	0.46	-0.03	-0.45	0.40	0.6516	-0.11	0.9108	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T2}	{August/September:T3}	18	18	0.14	0.20	-0.06	-0.23	0.12	0.1038	-0.64	0.5271	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T2}	{August/September:T4}	18	18	0.14	0.24	-0.10	-0.25	0.07	0.2626	-1.18	0.2448	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T2}	{October/November:T1}	18	18	0.14	0.16	-0.02	-0.20	0.17	0.047	-0.13	0.8957	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T2}	{October/November:T2}	18	18	0.14	0.13	0.01	-0.12	0.14	0.7752	0.15	0.8795	Bilateral

Time*Transect	Gastropodalog(x+1)	{August/September:T2}	{October/November:T3}	18	18	0.14	0.30	-0.16	-0.41	0.10	0.0006	-1.25	0.2230	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T2}	{October/November:T4}	18	18	0.14	0.46	-0.32	-0.65	0.03	<0.0001	-1.92	0.0688	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T3}	{August/September:T4}	18	18	0.20	0.24	-0.04	-0.23	0.15	0.6027	-0.40	0.6887	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T3}	{October/November:T1}	18	18	0.20	0.16	0.04	-0.17	0.25	0.706	0.40	0.6896	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T3}	{October/November:T2}	18	18	0.20	0.13	0.07	-0.10	0.23	0.0575	0.77	0.4464	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T3}	{October/November:T3}	18	18	0.20	0.30	-0.10	-0.38	0.17	0.0504	-0.75	0.4567	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T3}	{October/November:T4}	18	18	0.20	0.46	-0.26	-0.61	0.09	0.0021	-1.51	0.1431	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T4}	{October/November:T1}	18	18	0.24	0.13	0.11	-0.12	0.28	0.3707	0.81	0.4248	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T4}	{October/November:T2}	18	18	0.24	0.30	-0.06	-0.05	0.26	0.1618	1.34	0.1885	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T4}	{October/November:T3}	18	18	0.24	0.46	-0.22	-0.33	0.20	0.0146	-0.49	0.6301	Bilateral
Time*Transect	Gastropodalog(x+1)	{August/September:T4}	{October/November:T4}	18	18	0.24	0.13	0.11	-0.57	0.13	0.0004	-1.32	0.2012	Bilateral
Time*Transect	Gastropodalog(x+1)	{October/November:T1}	{October/November:T2}	18	18	0.16	0.13	0.03	-0.16	0.20	0.0242	0.25	0.8082	Bilateral
Time*Transect	Gastropodalog(x+1)	{October/November:T1}	{October/November:T3}	18	18	0.16	0.30	-0.14	-0.42	0.14	0.1104	-1.04	0.3072	Bilateral
Time*Transect	Gastropodalog(x+1)	{October/November:T1}	{October/November:T4}	18	18	0.16	0.46	-0.30	-0.66	0.06	0.0061	-1.73	0.0959	Bilateral
Time*Transect	Gastropodalog(x+1)	{October/November:T2}	{October/November:T3}	18	18	0.13	0.30	-0.17	-0.42	0.09	0.0002	-1.34	0.1926	Bilateral
Time*Transect	Gastropodalog(x+1)	{October/November:T2}	{October/November:T4}	18	18	0.13	0.46	-0.33	-0.66	0.02	<0.0001	-1.99	0.0607	Bilateral
Time*Transect	Gastropodalog(x+1)	{October/November:T3}	{October/November:T4}	18	18	0.30	0.46	-0.16	-0.55	0.24	0.2214	-0.81	0.4224	Bilateral

Table N9. The only significant difference was five gastropods (T-Test).

Classification	Variable	Group 1	Group 2	n(1)	n(2)	Mean(1)	Mean(2)	Mean(1)-Mean(2)	LI(95)	LS(95)	pHomVar	T	p-value	Test
Zone*Transect	Gastropodalog(x+1)	{aquatic:T1}	{aquatic:T2}	18	18	0.38	0.1	0.28	-0.02	0.57	0.0001	1.92	0.0681	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T1}	{aquatic:T3}	18	18	0.38	0.29	0.09	-0.27	0.45	0.5641	0.50	0.6231	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T1}	{aquatic:T4}	18	18	0.38	0.56	-0.18	-0.59	0.22	0.7545	-0.93	0.3570	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T1}	{sand:T1}	18	18	0.38	0.21	0.17	-0.17	0.50	0.1303	1.01	0.3218	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T1}	{sand:T2}	18	18	0.38	0.18	0.20	-0.09	0.49	<0.0001	1.42	0.1720	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T1}	{sand:T3}	18	18	0.38	0.21	0.17	-0.14	0.48	0.0066	1.11	0.2780	Bilateral

Zone*Transect	Gastropodalog(x+1)	{aquatic:T1}	{sand:T4}	18	18	0.38	0.13	0.25	-0.05	0.55	0.0003	1.70	0.1052	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T2}	{aquatic:T3}	18	18	0.1	0.29	-0.19	-0.45	0.07	0.0007	-1.48	0.1532	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T2}	{aquatic:T4}	18	18	0.1	0.56	-0.46	-0.78	-0.14	<0.0001	-3.00	0.0068	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T2}	{sand:T1}	18	18	0.1	0.21	-0.11	-0.33	0.10	0.0014	-1.06	0.2969	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T2}	{sand:T2}	18	18	0.1	0.18	-0.08	-0.20	0.05	0.4019	-1.22	0.2300	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T2}	{sand:T3}	18	18	0.1	0.21	-0.11	-0.28	0.06	0.1876	-1.30	0.2008	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T2}	{sand:T4}	18	18	0.1	0.13	-0.03	-0.17	0.12	0.7774	-0.41	0.6835	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T3}	{aquatic:T4}	18	18	0.29	0.56	-0.27	-0.65	0.11	0.3751	-1.47	0.1518	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T3}	{sand:T1}	18	18	0.29	0.21	0.08	-0.23	0.38	0.3429	0.51	0.6143	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T3}	{sand:T2}	18	18	0.29	0.18	0.11	-0.15	0.37	<0.0001	0.90	0.3809	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T3}	{sand:T3}	18	18	0.29	0.21	0.08	-0.20	0.36	0.0289	0.58	0.5649	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T3}	{sand:T4}	18	18	0.29	0.13	0.16	-0.11	0.42	0.0018	1.23	0.2298	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T4}	{sand:T1}	18	18	0.56	0.21	0.35	-9.10E-04	0.70	0.0698	2.03	0.0506	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T4}	{sand:T2}	18	18	0.56	0.18	0.38	0.07	0.70	<0.0001	2.55	0.0197	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T4}	{sand:T3}	18	18	0.56	0.21	0.35	0.02	0.68	0.0028	2.20	0.0380	Bilateral
Zone*Transect	Gastropodalog(x+1)	{aquatic:T4}	{sand:T4}	18	18	0.56	0.13	0.43	0.11	0.75	0.0001	2.79	0.0110	Bilateral
Zone*Transect	Gastropodalog(x+1)	{sand:T1}	{sand:T2}	18	18	0.21	0.18	0.03	-0.17	0.24	0.0001	0.34	0.7336	Bilateral
Zone*Transect	Gastropodalog(x+1)	{sand:T1}	{sand:T3}	18	18	0.21	0.21	2.80E-03	-0.23	0.24	0.2028	0.02	0.9807	Bilateral
Zone*Transect	Gastropodalog(x+1)	{sand:T1}	{sand:T4}	18	18	0.21	0.13	0.08	-0.14	0.30	0.0231	0.77	0.4470	Bilateral
Zone*Transect	Gastropodalog(x+1)	{sand:T2}	{sand:T3}	18	18	0.18	0.21	-0.03	-0.19	0.13	0.0338	-0.41	0.6867	Bilateral
Zone*Transect	Gastropodalog(x+1)	{sand:T2}	{sand:T4}	18	18	0.18	0.13	0.05	-0.09	0.18	0.2639	0.72	0.4748	Bilateral
Zone*Transect	Gastropodalog(x+1)	{sand:T3}	{sand:T4}	18	18	0.21	0.13	0.08	-0.09	0.25	0.2980	0.93	0.3597	Bilateral

Table N10.Significant differences in the gastropods abundance were found between variables zone and beach. The null hypothesis is accepted (T-Test).

Classification	Variable	Group 1	Group 2	n(1)	n(2)	Mean(1)	Mean(2)	Mean(1)-Mean(2)	LI(95)	LS(95)	pHomVar	T	p-value	Test
Zone*Beach	Gastropodalog(x+1)	{aquatic:Añasco}	{aquatic:CaboRojo}	24	24	0.17	0.76	-0.59	-0.88	-0.28	<0.0001	-3.97	0.0005	Bilateral
Zone*Beach	Gastropodalog(x+1)	{aquatic:Añasco}	{sand:Rincón}	24	24	0.17	0.06	0.11	2.10E-04	0.23	0.0844	2.02	0.0496	Bilateral
Zone*Beach	Gastropodalog(x+1)	{aquatic:CaboRojo}	{aquatic:Rincón}	24	24	0.76	0.06	0.70	0.40	0.98	<0.0001	4.86	0.0001	Bilateral
Zone*Beach	Gastropodalog(x+1)	{aquatic:CaboRojo}	{sand:Añasco}	24	24	0.76	0.15	0.61	0.31	0.90	<0.0001	4.23	0.0003	Bilateral

Zone*Beach	Gastropodalog(x+1)	{aquatic:CaboRojo}	{sand:Cabo Rojo}	24	24	0.76	0.34	0.42	0.1	0.73	0.0038	2.64	0.0121	Bilateral
Zone*Beach	Gastropodalog(x+1)	{aquatic:CaboRojo}	{sand:Rincón}	24	24	0.76	0.06	0.70	0.40	0.99	<0.0001	4.90	<0.0001	Bilateral
Zone*Beach	Gastropodalog(x+1)	{aquatic:Rincón}	{sand:Cabo Rojo}	24	24	0.06	0.34	-0.28	-0.44	-0.11	0.0001	-3.44	0.0017	Bilateral
Zone*Beach	Gastropodalog(x+1)	{sand:Añasco}	{sand:Cabo Rojo}	24	24	0.15	0.34	-0.19	-0.36	-0.02	0.0023	-2.33	0.0259	Bilateral
Zone*Beach	Gastropodalog(x+1)	{sand:CaboRojo}	{sand:Rincón}	24	24	0.34	0.06	0.28	0.12	0.45	0.0003	3.50	0.0014	Bilateral

Table N11. T-Test showed that there were only two differences: in variable time versus zone in the second sampling and the aquatic and sand zones of the same time.

Classification	Variable	Group 1	Group 2	n(1)	n(2)	Mean(1)	Mean(2)	Mean(1)-Mean(2)	LI(95)	LS(95)	pHomVar	T	p-value	Test
Time*Zone	Gastropodalog(x+1)	{August/September:aquatic}	{August/September:sand}	36	36	0.25	0.25	-2.60E-03	-0.18	0.18	0.1821	-0.03	0.9771	Bilateral
Time*Zone	Gastropodalog(x+1)	{August/September:aquatic}	{October/November:aquatic}	36	36	0.25	0.41	-0.16	-0.40	0.08	0.0465	-1.33	0.1886	Bilateral
Time*Zone	Gastropodalog(x+1)	{August/September:aquatic}	{October/November:sand}	36	36	0.25	0.11	0.14	-0.01	0.29	<0.0001	1.85	0.0708	Bilateral
Time*Zone	Gastropodalog(x+1)	{August/September:sand}	{October/November:aquatic}	36	36	0.25	0.41	-0.16	-0.39	0.07	0.0011	-1.40	0.1682	Bilateral
Time*Zone	Gastropodalog(x+1)	{August/September:sand}	{October/November:sand}	36	36	0.25	0.11	0.14	0.02	0.27	0.0003	2.27	0.0274	Bilateral
Time*Zone	Gastropodalog(x+1)	{October/November:aquatic}	{October/November:sand}	36	36	0.41	0.11	0.30	0.09	0.51	<0.0001	2.93	0.0056	Bilateral

Table N12. T-Test showed a difference in the number of gastropods between the variables of beach and transects.

Classification	Variable	Group 1	Group 2	n(1)	n(2)	Mean(1)	Mean(2)	Mean(1)-Mean(2)	LI(95)	LS(95)	pHomVar	T	p-value	Test
Transect*Beach	Gastropodalog(x+1)	{T1:Añasco}	{T1:CaboRojo}	12	12	0.06	0.75	-0.69	-1.08	-0.29	0.0001	-3.77	0.0027	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T1:Añasco}	{T2:CaboRojo}	12	12	0.06	0.24	-0.18	-0.33	-0.02	0.423	-2.40	0.0254	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T1:Añasco}	{T3:CaboRojo}	12	12	0.06	0.55	-0.49	-0.83	-0.13	0.0003	-2.97	0.0108	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T1:Añasco}	{T4:CaboRojo}	12	12	0.06	0.65	-0.59	-1.07	-0.11	<0.0001	-2.67	0.0204	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T1:CaboRojo}	{T1:Rincón}	12	12	0.75	0.06	0.69	0.29	1.08	0.0001	3.77	0.0027	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T1:CaboRojo}	{T2:CaboRojo}	12	12	0.75	0.24	0.51	0.11	0.91	0.0009	2.75	0.0165	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T1:CaboRojo}	{T2:Rincón}	12	12	0.75	0.00	0.75	0.36	1.14	<0.0001	4.26	0.0014	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T1:CaboRojo}	{T3:Añasco}	12	12	0.75	0.20	0.55	0.15	0.96	0.0036	2.93	0.0111	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T1:CaboRojo}	{T3:Rincón}	12	12	0.75	0.00	0.75	0.36	1.14	<0.0001	4.26	0.0014	Bilateral

Transect*Beach	Gastropodalog(x+1)	{T1:CaboRojo}	{T4:Añasco}	12	12	0.75	0.20	0.55	0.14	0.95	0.0031	2.90	0.0017	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T1:CaboRojo}	{T4:Rincón}	12	12	0.75	0.18	0.57	0.17	0.98	0.0037	3.02	0.0091	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T1:Rincón}	{T2:CaboRojo}	12	12	0.06	0.24	-0.18	-0.33	-0.02	0.4230	-2.40	0.0254	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T1:Rincón}	{T3:CaboRojo}	12	12	0.06	0.55	-0.49	-0.83	-0.13	0.0003	-2.97	0.0108	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T1:Rincón}	{T4:CaboRojo}	12	12	0.06	0.65	-0.59	-1.07	-0.11	<0.0001	-2.67	0.0204	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T2:Añasco}	{T2:Rincón}	12	12	0.18	0.00	0.18	0.05	0.30	<0.0001	3.02	0.0116	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T2:Añasco}	{T3:CaboRojo}	12	12	0.18	0.55	-0.37	-0.73	-0.01	0.0028	-2.23	0.0425	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T2:Añasco}	{T3:Rincón}	12	12	0.18	0.00	0.18	0.05	0.30	<0.0001	3.02	0.0116	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T2:CaboRojo}	{T2:Rincón}	12	12	0.24	0.00	0.24	0.11	0.37	<0.0001	4.16	0.0016	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T2:CaboRojo}	{T3:Rincón}	12	12	0.24	0.00	0.24	0.11	0.37	<0.0001	4.16	0.0016	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T2:Rincón}	{T3:Añasco}	12	12	0.00	0.20	-0.20	-0.35	-0.05	<0.0001	-2.93	0.0138	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T2:Rincón}	{T4:Añasco}	12	12	0.00	0.20	-0.20	-0.35	-0.06	<0.0001	-3.08	0.0105	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T2:Rincón}	{T4:CaboRojo}	12	12	0.00	0.65	-0.65	-1.13	-0.18	<0.0001	-3.03	0.0115	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T2:Rincón}	{T4:Rincón}	12	12	0.00	0.18	-0.18	-0.33	-0.03	<0.0001	-2.64	0.0228	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T3:Añasco}	{T3:Rincón}	12	12	0.20	0.00	0.20	0.05	0.35	<0.0001	2.93	0.0138	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T3:CaboRojo}	{T3:Rincón}	12	12	0.55	0.00	0.55	0.20	0.89	<0.0001	3.51	0.0049	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T3:CaboRojo}	{T4:Rincón}	12	12	0.55	0.18	0.37	4.40E-03	0.73	0.0106	2.16	0.0476	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T3:Rincón}	{T4:Añasco}	12	12	0.00	0.20	-0.20	-0.35	-0.06	<0.0001	-3.08	0.0105	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T3:Rincón}	{T4:CaboRojo}	12	12	0.00	0.65	-0.65	-1.13	-0.18	<0.0001	-3.03	0.0115	Bilateral
Transect*Beach	Gastropodalog(x+1)	{T3:Rincón}	{T4:Rincón}	12	12	0.00	0.18	-0.18	-0.33	-0.03	<0.0001	-2.64	0.0228	Bilateral

Appendix O

Table O1. Shapiro Wilks distributions for the variables time, transect, beach and zone. P>0.05, meaning that the distributions were not normal.

Time	Beach	Transect	Zone	Variable	n	Mean	D.E.	W*	p(Unilateral D)
August/September	Añasco	T1	aquatic	Bivalvia Log(x+1)	3	0.10	0.17	0.75	<0.0001
August/September	Añasco	T3	sand	Bivalvia Log(x+1)	3	1.15	0.07	0.75	<0.0001
August/September	Añasco	T4	aquatic	Bivalvia Log(x+1)	3	0.70	0.35	0.75	<0.0001
August/September	Cabo Rojo	T1	aquatic	Bivalvia Log(x+1)	3	0.10	0.17	0.75	<0.0001
August/September	Cabo Rojo	T1	sand	Bivalvia Log(x+1)	3	0.10	0.17	0.75	<0.0001
August/September	Cabo Rojo	T2	aquatic	Bivalvia Log(x+1)	3	0.10	0.17	0.75	<0.0001
August/September	Cabo Rojo	T2	sand	Bivalvia Log(x+1)	3	0.10	0.17	0.75	<0.0001
August/September	Cabo Rojo	T3	aquatic	Bivalvia Log(x+1)	3	0.30	0.00	0.06	<0.0001
August/September	Cabo Rojo	T4	aquatic	Bivalvia Log(x+1)	3	0.10	0.17	0.75	<0.0001
August/September	Mayagüez	T1	sand	Bivalvia Log(x+1)	3	0.42	0.10	0.75	<0.0001
August/September	Mayagüez	T2	sand	Bivalvia Log(x+1)	3	0.10	0.17	0.75	<0.0001
August/September	Mayagüez	T3	aquatic	Bivalvia Log(x+1)	3	0.16	0.28	0.75	<0.0001
August/September	Mayagüez	T3	sand	Bivalvia Log(x+1)	3	0.20	0.17	0.75	<0.0001
August/September	Mayagüez	T4	aquatic	Bivalvia Log(x+1)	3	0.36	0.10	0.75	<0.0001
August/September	Mayagüez	T4	sand	Bivalvia Log(x+1)	3	0.20	0.17	0.75	<0.0001
August/September	Rincón	T1	aquatic	Bivalvia Log(x+1)	3	0.23	0.40	0.75	<0.0001
August/September	Rincón	T3	sand	Bivalvia Log(x+1)	3	0.10	0.17	0.75	<0.0001
October/November	Añasco	T1	aquatic	Bivalvia Log(x+1)	3	0.10	0.17	0.75	<0.0001
October/November	Añasco	T1	sand	Bivalvia Log(x+1)	3	0.48	0.00	0.10	<0.0001
October/November	Añasco	T2	aquatic	Bivalvia Log(x+1)	3	0.10	0.17	0.75	<0.0001
October/November	Añasco	T2	sand	Bivalvia Log(x+1)	3	0.40	0.17	0.75	<0.0001
October/November	Añasco	T4	aquatic	Bivalvia Log(x+1)	3	0.28	0.49	0.75	<0.0001
October/November	Añasco	T4	sand	Bivalvia Log(x+1)	3	0.36	0.10	0.75	<0.0001
October/November	Cabo Rojo	T1	aquatic	Bivalvia Log(x+1)	3	0.16	0.28	0.75	<0.0001
October/November	Cabo Rojo	T2	sand	Bivalvia Log(x+1)	3	0.63	0.06	0.75	<0.0001
October/November	Cabo Rojo	T4	aquatic	Bivalvia Log(x+1)	3	0.32	0.28	0.75	<0.0001
October/November	Cabo Rojo	T4	sand	Bivalvia Log(x+1)	3	0.68	0.17	0.75	<0.0001
October/November	Mayagüez	T1	aquatic	Bivalvia Log(x+1)	3	0.10	0.17	0.75	<0.0001
October/November	Mayagüez	T2	aquatic	Bivalvia Log(x+1)	3	0.16	0.28	0.75	<0.0001
October/November	Mayagüez	T3	aquatic	Bivalvia Log(x+1)	3	0.16	0.28	0.75	<0.0001
October/November	Mayagüez	T4	aquatic	Bivalvia Log(x+1)	3	0.10	0.17	0.75	<0.0001
October/November	Rincón	T2	aquatic	Bivalvia Log(x+1)	3	0.10	0.17	0.75	<0.0001
October/November	Rincón	T2	sand	Bivalvia Log(x+1)	3	0.10	0.17	0.75	<0.0001
October/November	Rincón	T4	sand	Bivalvia Log(x+1)	3	0.20	0.17	0.75	<0.0001

Table O2. Shapiro Wilks analysis p>0.05, which indicates not normal data.

Time	Transect	Beach	Zone	Variable	n	Mean	S.D.	W*	P(Unilateral D)
August /September	T1	Añasco	aquatic	Gastropoda log(x+1)	3	0.10	0.17	0.75	<0.0001
August /September	T1	Cabo Rojo	aquatic	Gastropoda log(x+1)	3	1.22	0.80	0.76	0.0320
August /September	T2	Añasco	aquatic	Gastropoda log(x+1)	3	0.20	0.35	0.75	<0.0001
August /September	T2	Añasco	sand	Gastropoda log(x+1)	3	0.20	0.17	0.75	<0.0001
August /September	T2	Cabo Rojo	aquatic	Gastropoda log(x+1)	3	0.10	0.17	0.75	<0.0001
August /September	T2	Cabo Rojo	sand	Gastropoda log(x+1)	3	0.36	0.10	0.75	<0.0001
August /September	T3	Añasco	aquatic	Gastropoda log(x+1)	3	0.23	0.40	0.75	<0.0001
August /September	T3	Añasco	sand	Gastropoda log(x+1)	3	0.36	0.10	0.75	<0.0001
August /September	T3	Cabo Rojo	aquatic	Gastropoda log(x+1)	3	0.10	0.17	0.75	<0.0001
August /September	T4	Añasco	aquatic	Gastropoda log(x+1)	3	0.20	0.17	0.75	<0.0001
August /September	T4	Añasco	sand	Gastropoda log(x+1)	3	0.16	0.28	0.75	<0.0001
August /September	T4	Rincón	aquatic	Gastropoda log(x+1)	3	0.32	0.28	0.75	<0.0001
August /September	T4	Rincón	sand	Gastropoda log(x+1)	3	0.20	0.35	0.75	<0.0001
October/November	T1	Añasco	aquatic	Gastropoda log(x+1)	3	0.16	0.28	0.75	<0.0001
October/November	T2	Añasco	sand	Gastropoda log(x+1)	3	0.10	0.17	0.75	<0.0001
October/November	T2	Añasco	sand	Gastropoda log(x+1)	3	0.20	0.17	0.75	<0.0001
October/November	T2	Cabo Rojo	aquatic	Gastropoda log(x+1)	3	0.20	0.35	0.75	<0.0001
October/November	T2	Cabo Rojo	sand	Gastropoda log(x+1)	3	0.30	0.00	0.06	<0.0001
October/November	T3	Añasco	aquatic	Gastropoda log(x+1)	3	0.10	0.17	0.75	<0.0001
October/November	T3	Añasco	sand	Gastropoda log(x+1)	3	0.10	0.17	0.75	<0.0001
October/November	T4	Añasco	sand	Gastropoda log(x+1)	3	0.16	0.28	0.75	<0.0001
October/November	T4	Rincón	aquatic	Gastropoda log(x+1)	3	0.20	0.17	0.75	<0.0001

Appendix P

Table P1. Tukey Test for sorting of sand in all selected beaches, according to the variable time (sampling). Different letters represent significant differences (*).

Time	d.f.	Medians	n	S.D.
October/November	55	1.44	32	0.03 A
August/September	55	1.44	32	0.03 A

Table P2. Tukey Test for the sorting of sand, according to the variable beach. Different letters represent significant differences (*).

Beach	d.f.	Medians	n	S.D.
Rincón	55	1.36	16	0.05A*
Mayagüez	55	1.39	16	0.05 A*
Añasco	55	1.42	16	0.05 A*
Cabo Rojo	55	1.64	16	0.05 B*

Table P3. Tukey Test for the sorting of sand in all selected beaches, according to the variable transect. Different letters represent significant differences (*).

Transect	d.f.	Medians	n	S.D.
T1	55	1.44	16	0.05A
T2	55	1.37	16	0.05 A
T3	55	1.47	16	0.05 A
T4	55	1.52	16	0.05 A

Table P4. Tukey Test for sorting of sand in all selected beaches, according to the variable zone (sand versus aquatic). Different letters represent significant differences (*).

Zone	d.f.	Medians	n	S.D.
aquatic	55	1.36	32	0.03 A*
sand	55	1.54	32	0.03 B*

Appendix Q

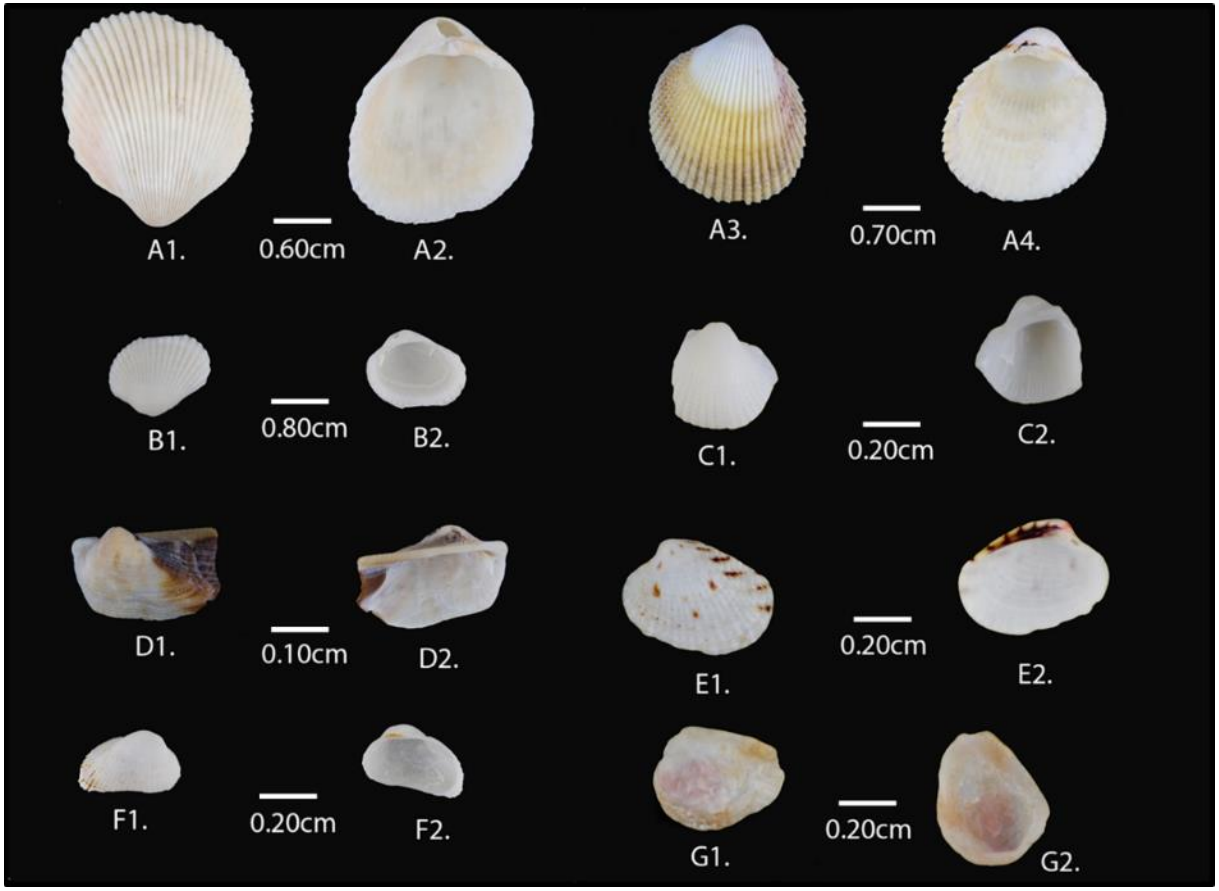

Plate Q1. Bivalves species found at Balneario Tres Hermanos beach, Añasco, in sampling 1 (August/September 2016). **A** *Acrosterigma magnum* **A1**. outer face, **A2.** inner face, **A3**. outer face and **A4**. inner face. **B**. *Adula sp* **B1**. outer face and **B2**. inner face. **C.** *Anadara chemnitzii* **C1**. outer face and **C2**. inner face. D. *Anadara notabilis* **D1**. outer face and **D2**. inner face. **E**. *Anadara sp* **E1**. outer face and **E2**. inner face. **F** *Anadara transversa* **F1**. outer face and **F2**. inner face. **G** *Anomia simplex* **G1**. outer face and **G2**. inner face.

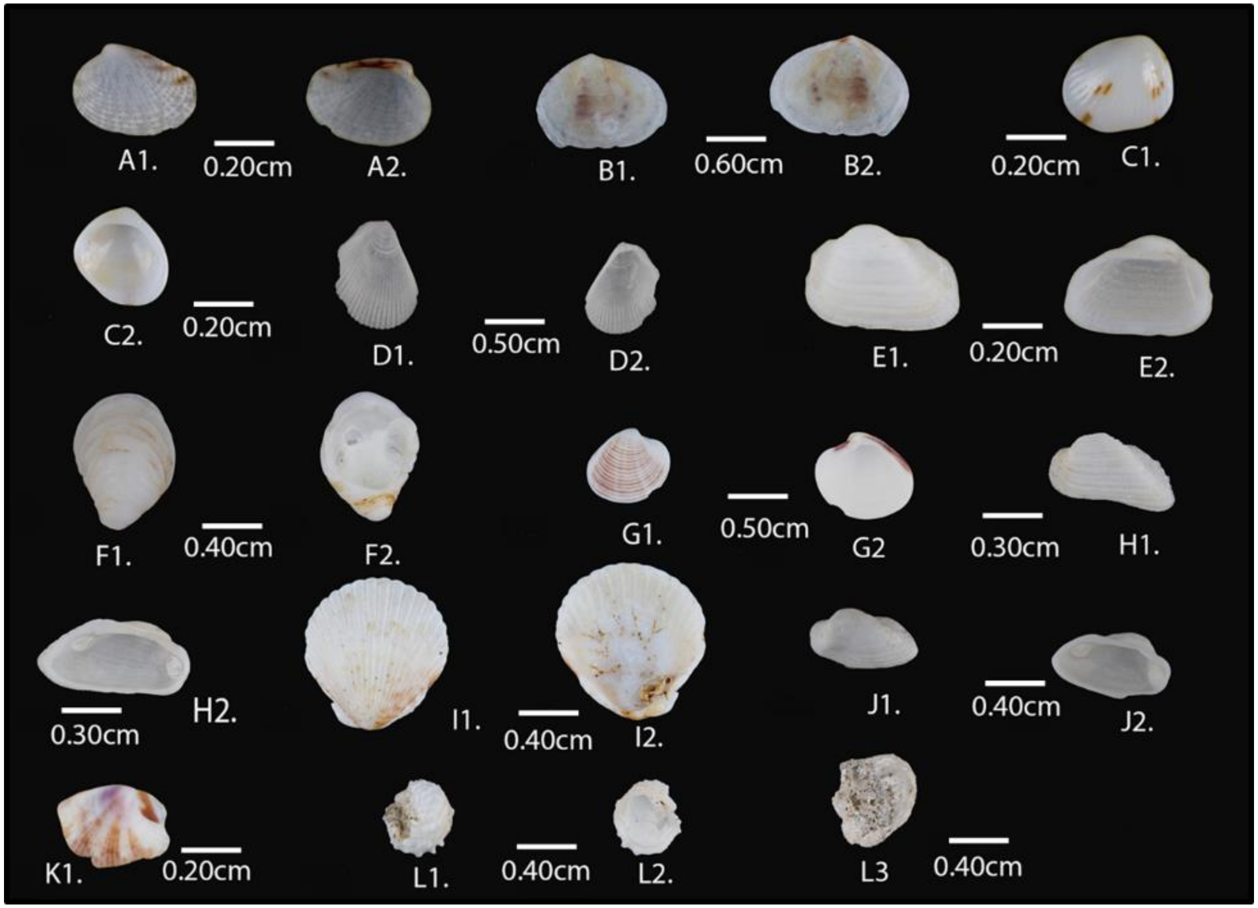

Plate Q2. Bivalves species found at Balneario Tres Hermanos beach, Añasco, in sampling 1 (August/September 2016). **A** *Gouldia sp.* **A1**. outer face and **A2**. inner face. **B** *Laciolina magna* **B1**. outer face and **B2.** inner face. **C** *Laevicardium mortoni* **C1**. outer face and **C2**. inner face. **D** *Lima scabra* **D1**. outer face and **D2**. inner face. **E** *Macoma sp.* **E1**. outer face and E2. inner face. **F** *Mytilopsis sp.* **F1** outer face and **F2.** inner face. **G** *Lamelliconcha circinata* **G1**. outer face and **G2**. inner face. **H** *Sphenia sp.* **H1**. outer face and **H2**. inner face. **I** *Trachycardium egmonitatum* **I1**. outer face and **I2**. inner face. **J** *Yoldia limatula* **J1**. outer face and **J2**. inner face. **K**. *Tivela sp*. outer face. **L** *Chama macerophylla* **L1**. outer face, **L2**. inner face and **L3**. *Chama macerophylla* fossil.

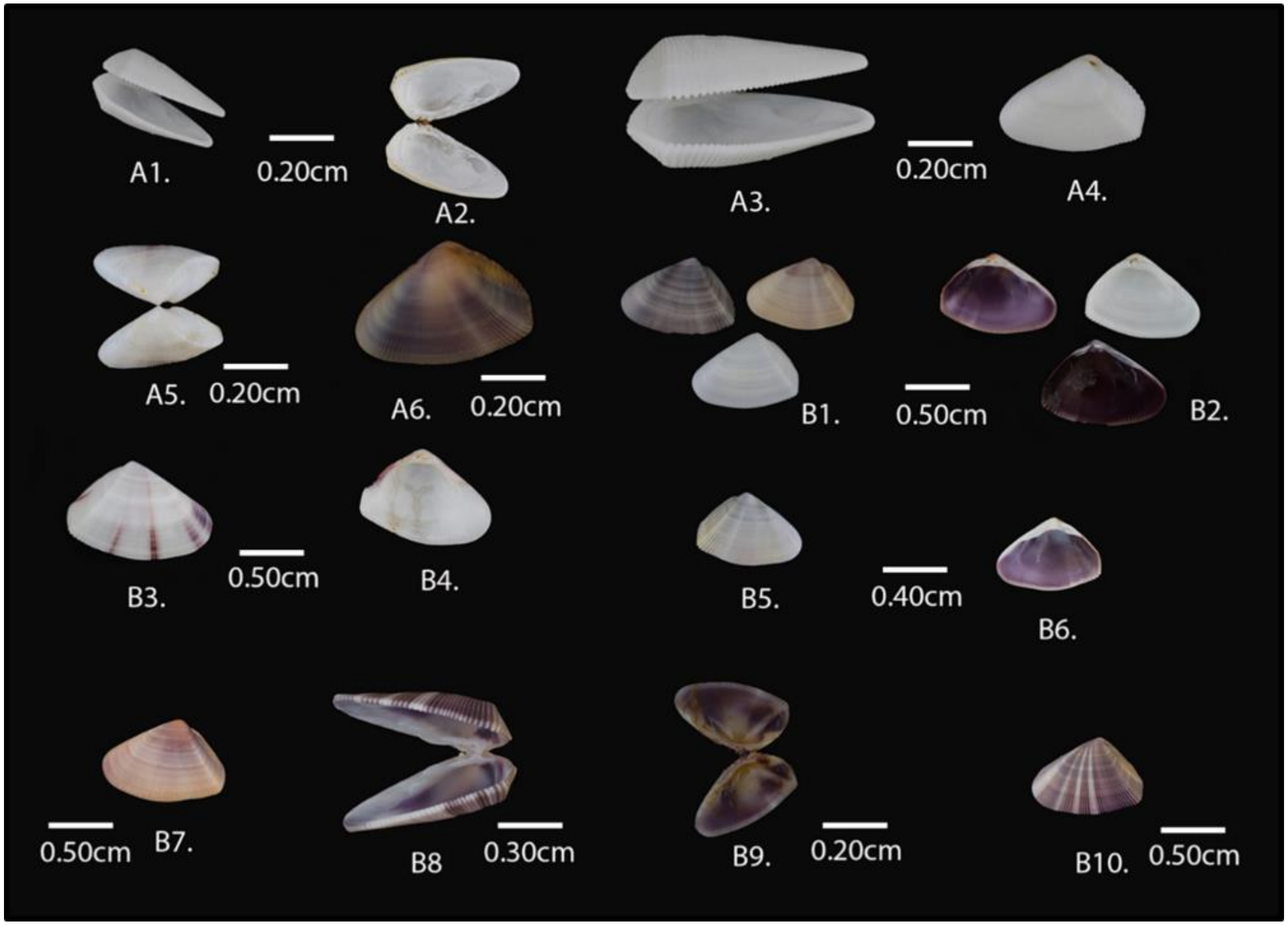

Plate Q3. Bivalves species found at Balneario Tres Hermanos beach, Añasco, in sampling 1 (August/September 2016). **A** *Donax striatus* **A1.** outer face, **A2**. inner face., **A3**. inner face, **A4**. outer face, **A5.** outer face and **A6** outer face. **B** *Donax denticulatus* **B1**. 3 specimens outer face, **B2**.3 species inner face, **B3**. outer face, **B4**.inner face, **B5**. outer face, **B6**. inner face, **B7**. outer face, **B8**. inner face, **B9**. inner face and **B10**. outer face.

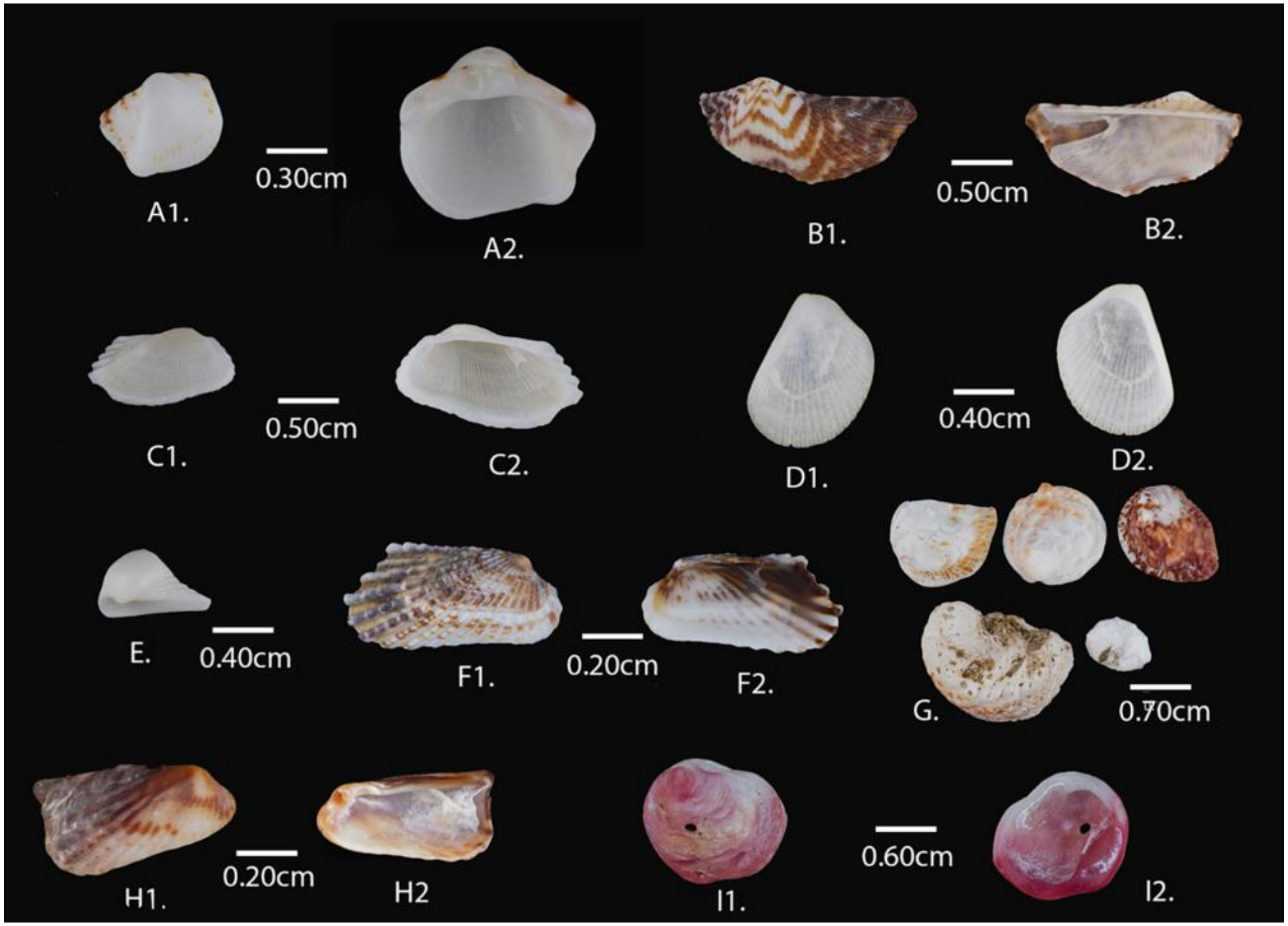

Plate Q4. Bivalves species found at Balneario Tres Hermanos beach, Añasco, in sampling 1 (August/September 2016). **A** *Arca sp.* **A1**. outer face, **A2**. inner face., **B.** *Arca zebra.* **B1**. outer face and **B2**. inner face. **C.** *Basterotia sp.* **C1**. outer face and **C2**. inner face. **D**. *Ischadium recurvum.* **D1**. outer face and **D2**. inner face**. E.** *Cardiomya sp.* outer face. **F**. *Carditamera gracilis*. **F1**. outer face and **F2.** inner face. **G**. *Chama macerophylla* outer face. **H**. *Cardita sp.* **H1**. outer face and **H2**. inner face. **I**. *Chama sarda*. **I1**. outer face and **I2**. inner face.

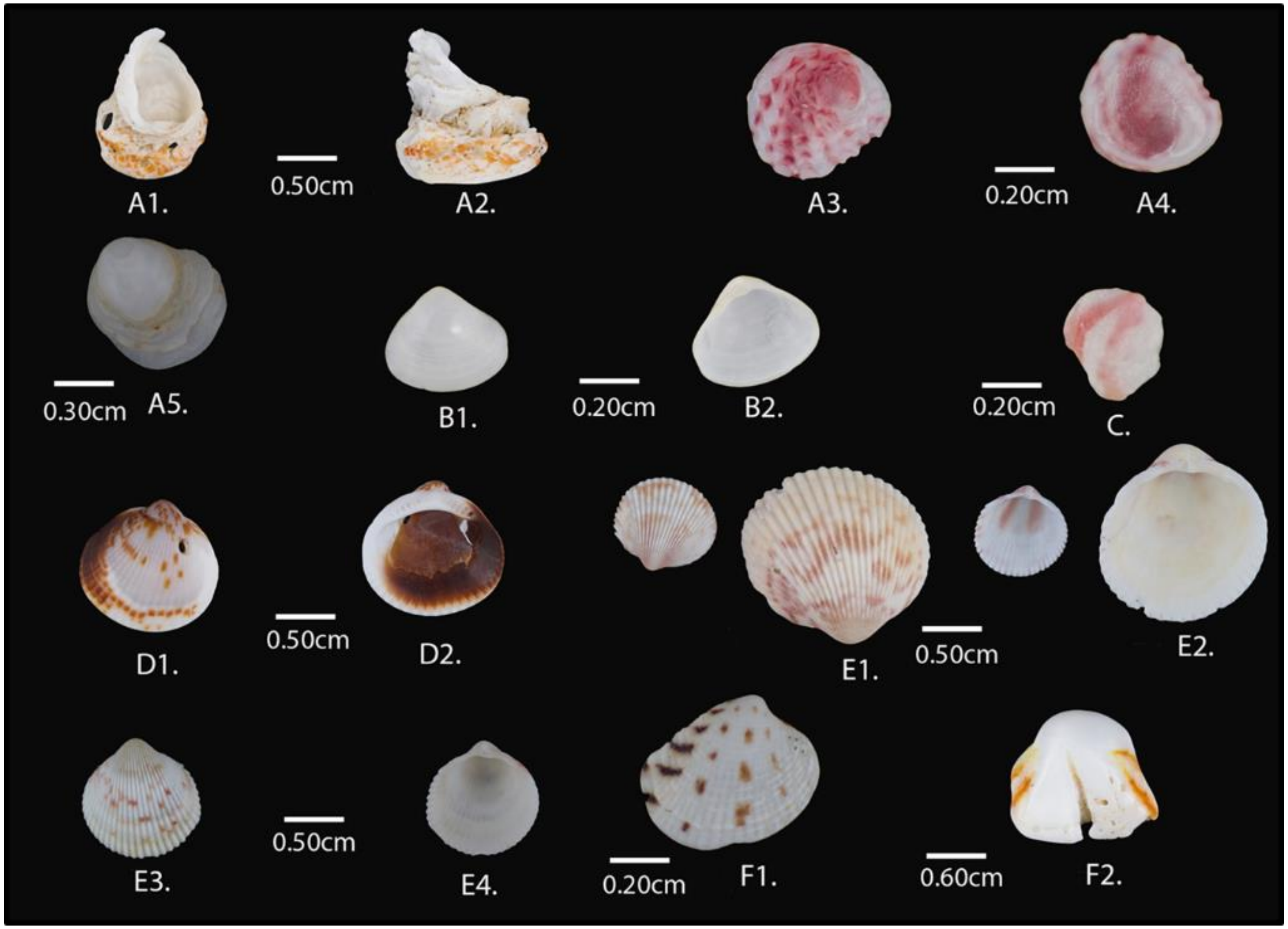

Plate Q5. Bivalves species found at Balneario Tres Hermanos beach, Añasco, in sampling 1 (August/September 2016). **A**. *Chama sp.* **A1.** inner face, **A2**. outer face, **A3**. outer face, **A4**. inner face and **A5**. outer face. **B**. *Basterotia sp.* **B1.** outer face and **B2.** inner face. **C.** *Erycina sp.* outer face. **D**. *Ischadium recurvum.* **D1**. outer face and **D2**. inner face. **E**. *Glycymeris pectinata*. **E1**. outer face, **E2**. inner face, **E3**. outer face and **E4**. inner face. **F.** *Glycymeris sp.* **F1**. outer face and **F2**. outer face.

Plate Q6. Gastropods species found at Balneario Tres Hermanos beach, Añasco, in sampling 1 (August/September 2016). **A**. *Nerita tessellate*. **A1**. inner face, **A2.** outer face.

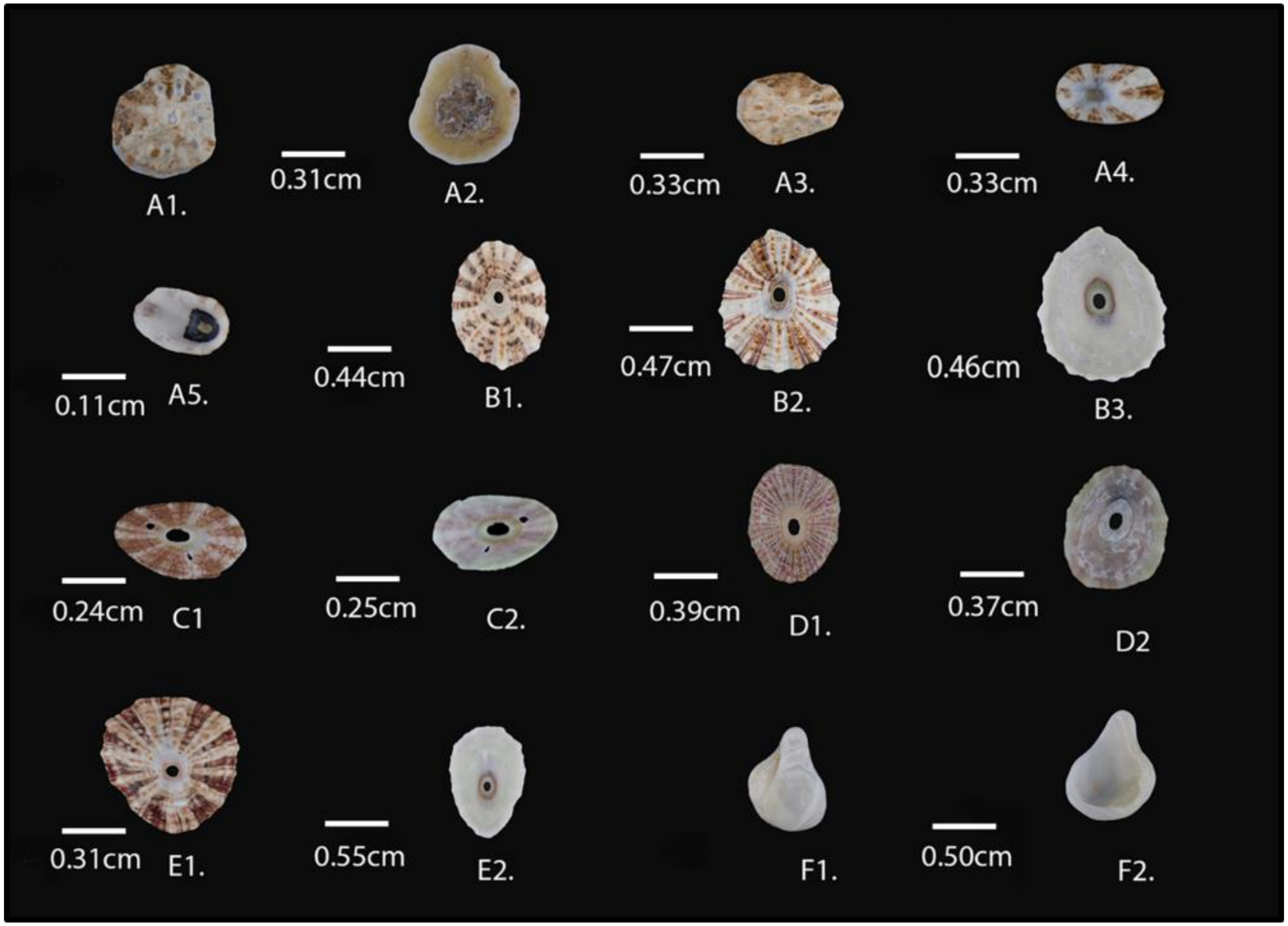

Plate Q7. Gastropods species found at Balneario Tres Hermanos beach, Añasco, in sampling 1 (August/September 2016). **A**. *Diodora aspera.* **A1**. outer face, **A2**. inner face., **A3**. outer face, **A4**. outer face and **A5**. inner face. **B**. *Diodora listeri*. **B1**. outer face, **B2**. outer face and **B3**.inner face. **C.** *Diodora sp.* **C1**. inner face and **C2.** inner face. **D**. *Fisurella fascicularis* **D1**. outer face and **D2**. inner face. **E**. *Fisurrella barbarensis*. **E1**.outer face, and **E2**. inner face**. F.** *Hipponix subrufus*. **F1**. outer face and **F2**. outer face.

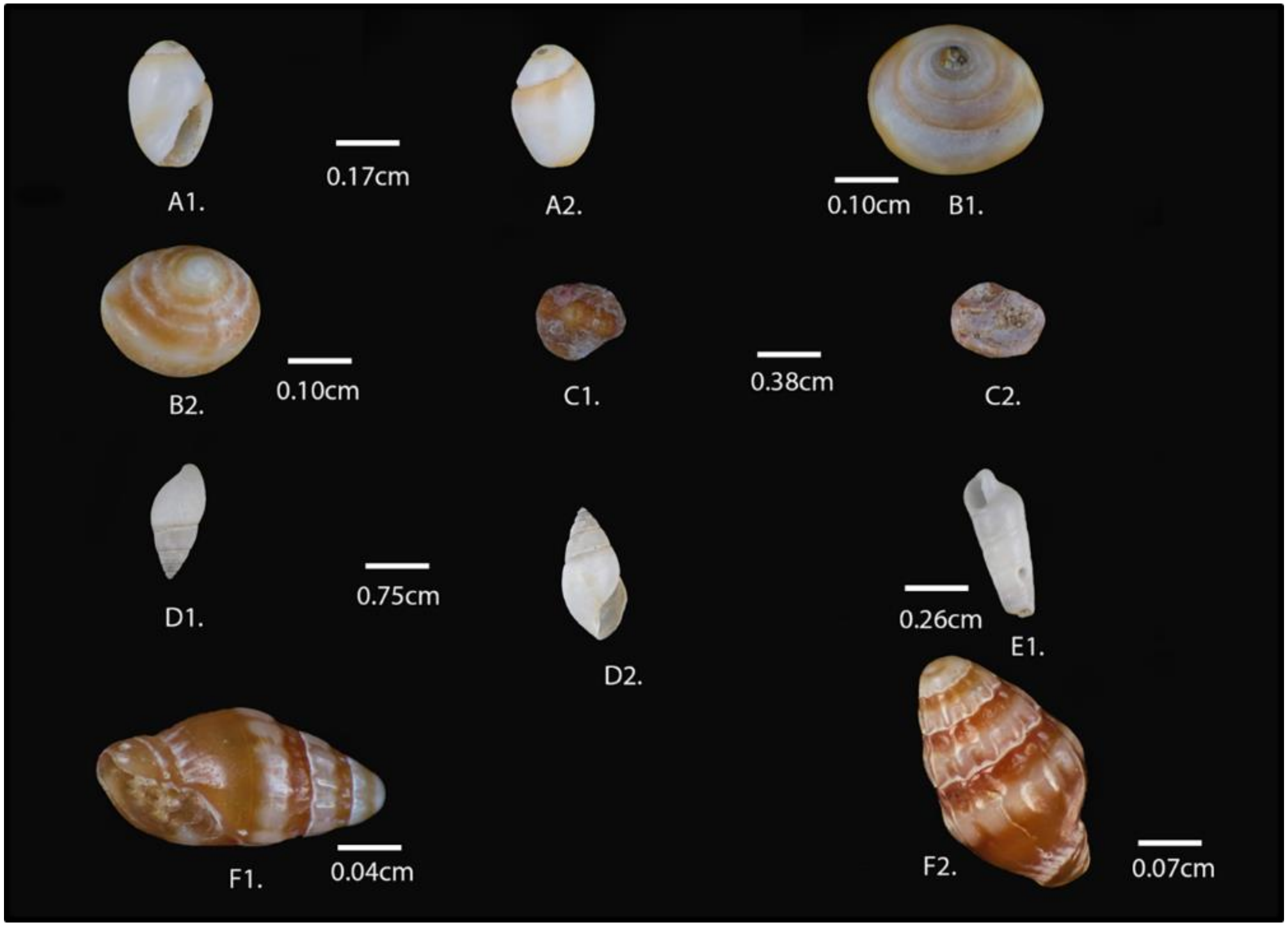

Plate Q8. Gastropods and bivalves species found at Balneario Tres Hermanos beach, Añasco, in sampling 1 (August/September 2016). **A**. *Olivella minuta.* **A1**. inner face and **A2**. outer face. **B**. *Psilaxis krebsii.* **B1**. inner face and **B2**. outer face. **C**. *Teskeyostrea sp.* **C1**. outer face and **C2.** inner face. **D**. *Zebina browniana.* **D1**. outer face and **D2**. inner face. **E1**. *Turbonilla elegans.* (outer and inner face). **F**. *Planaxis sp.* **F1**. inner face and **F2.** outer face.

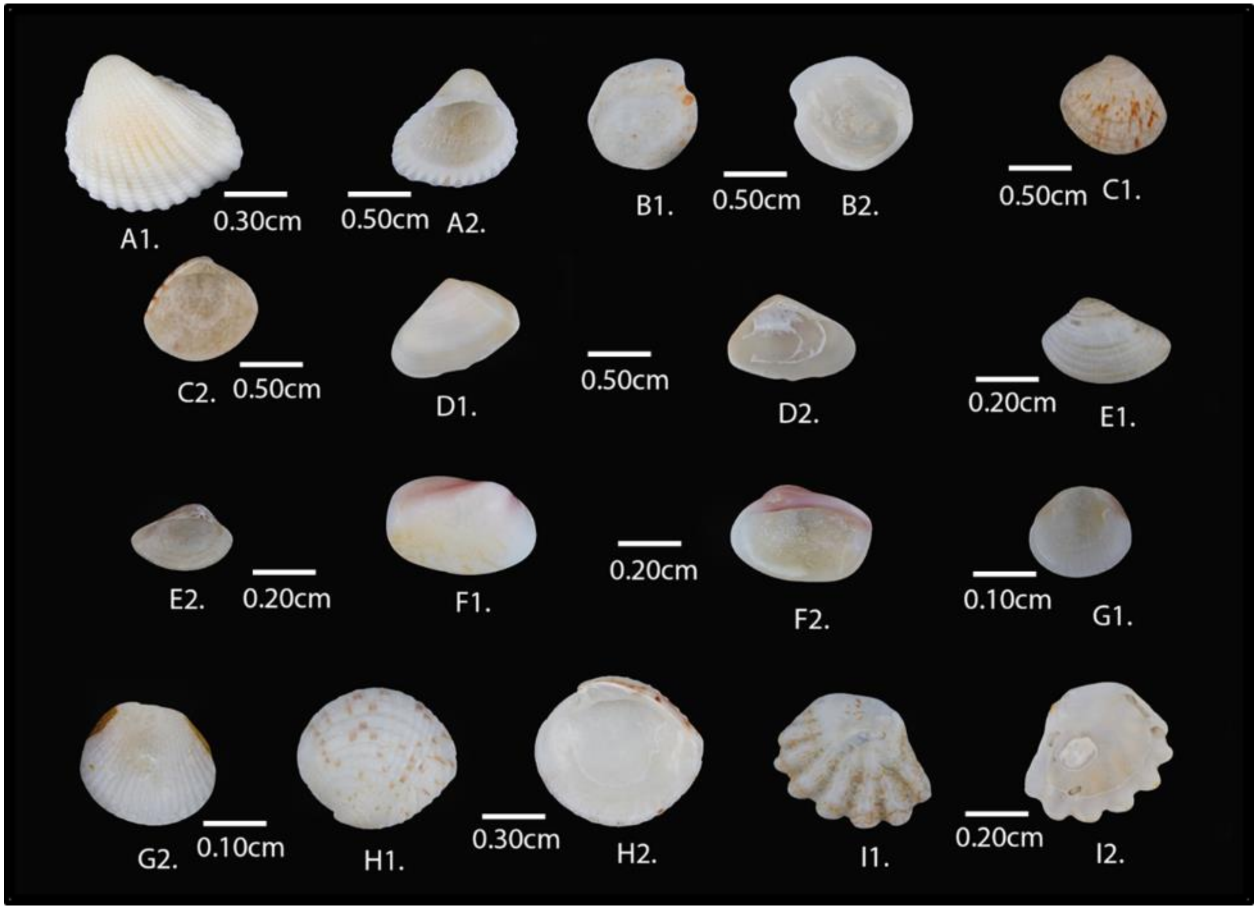

Plate Q9. Bivalves species found at El Combate beach, Cabo Rojo, in sampling 1 (August/September 2016). **A**. *Americardia media*. **A1.** outer face and **A2**. inner face**. B**. *Anomia simplex.* **B1**. outer face and **B2**. inner face. **C**. *Chione cancellata.* **C1**. outer face and **C2.** inner face. **D**. *Donax denticulatus.* **D1**. outer face and **D2**. inner face. E. *Semelina nuculoides* **E1**. outer face and **E2**. inner face. **F**. *Microcardium sp.* **F1.** outer face and **F2**. inner face. **G**. *Glycymeris decussata.* **G1**. inner face and **G2**. outer face. **H.** *Chione sp.* **H1**. outer face and **H2**. inner face. **I.** *Plicatula gibbosa*. **I1**. outer face and **I2.** inner face.

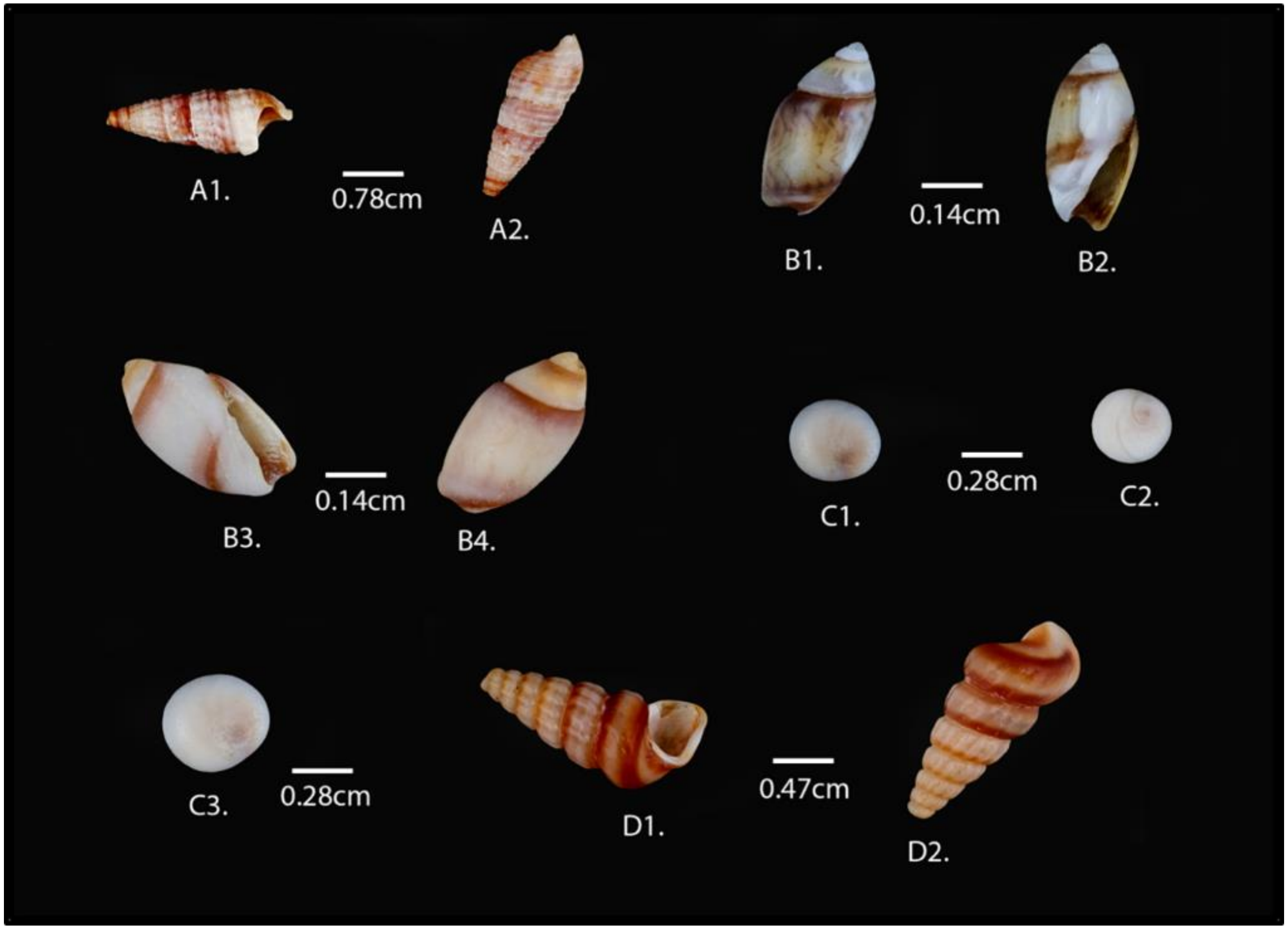

Plate Q10. Gastropods species found at El Combate beach, Cabo Rojo, in sampling 1 (August/September 2016). **A.** *Lampanella sp.* **B1**. inner face and **A2** outer face. **B**. *Olivella minuta* **B1**. outer face, **B2**. inner face, **B3**. inner face and **B4**. outer face. **C**. *Sigapatella sp.* **C1**. outer face, **C2**. inner face and **C3**. outer face. **D**. *Turbonilla elegans.* **D1**. inner face and **D2.** outer face.

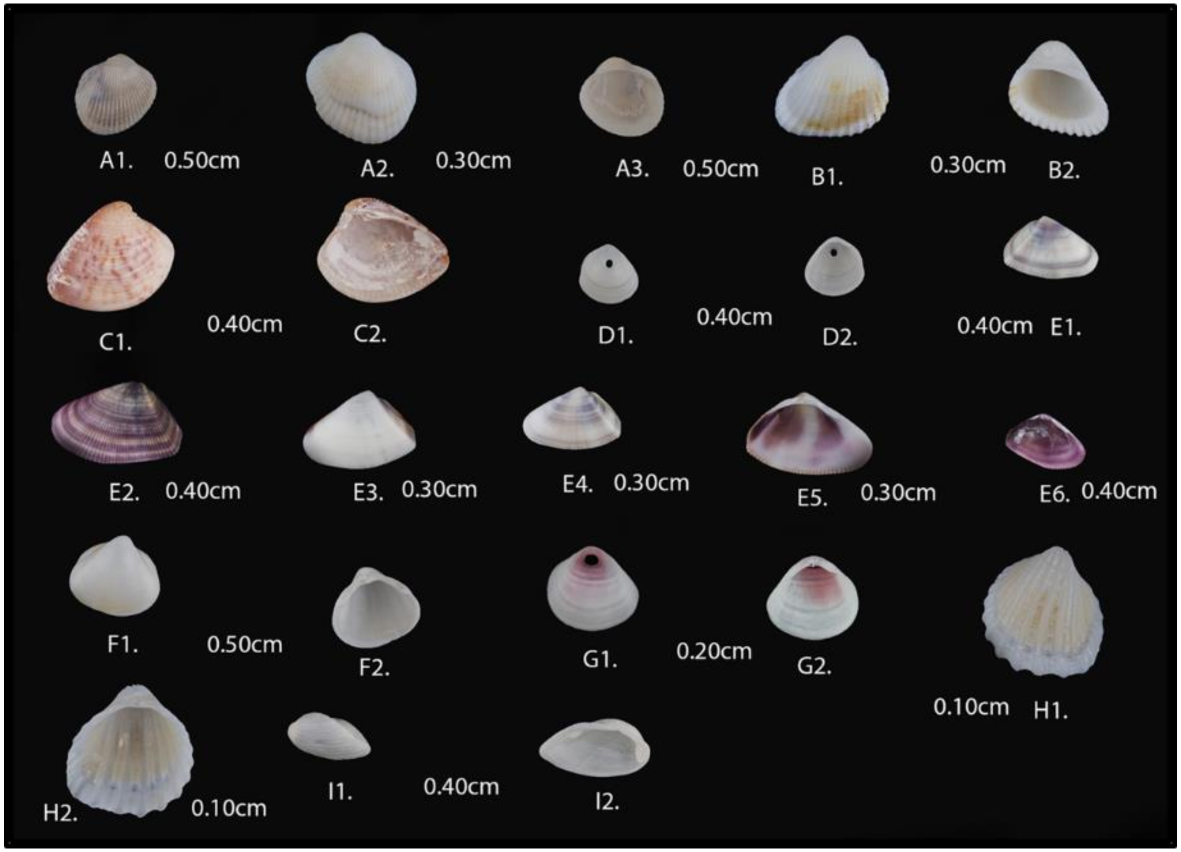

Plate Q11. Bivalves species found at El Maní, Mayagüez beach in sampling 1 (August/September 2016). These species were also found at same beach in sampling 2 (October/November). **A.** *Americardia guppyi.* **A1**. outer face, **A2**. outer face and **A3**. inner face. **B**. *Americardia sp.* **B1**. outer face and B2. inner face. **C.** *Puberella intrapurpurea.* **C1**. outer face and **C2**. inner face. **D.** *Diplodonta sp.* D1. outer face and **D2**. inner face. **E**. *Donax denticulatus.* **E1**. outer face, **E2**. outer face, E3. outer face, **E4**. outer face, E5. inner face and **E6**. inner face. **F**. *Mulinia sp.* **F1**. outer face and **F2**. inner face. **G**. *Strigilia carnaria.* **G1.** outer face and **G2.** inner face. **H.** *Trigoniocardia antillarum.* **H1**. outer face and **H2** inner face. **I**. *Yoldia limatula* **I1**. outer face and **I2.** inner face.

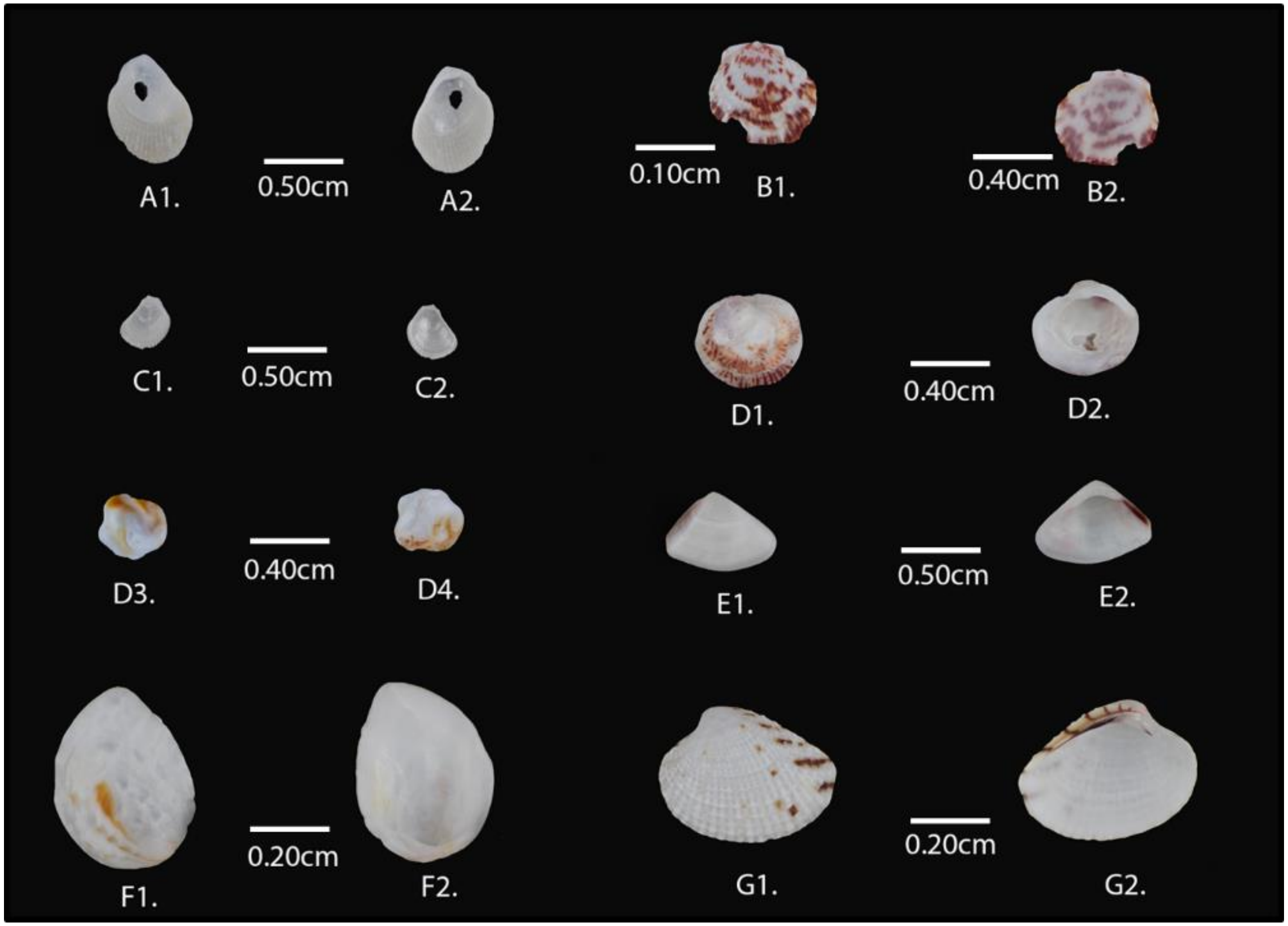

Plate Q12. Bivalves species found at Córcega beach, Rincón, in sampling 1 (August/September 2016). **A.** *Lima sp.* **A1**. outer face, and **A2**. outer face. **B.** *Argopecten sp.* **B1**. outer face and **B2**. inner face. **C** *Brachidontes sp.* **C1**. outer face and **C2**. inner face. **D** *Chama sp.* **D1.** inner face and **D2**. outer face. E. *Donax striatus.* **E1**. outer face and **E2**. outer face. **F**. *Anomia simplex.* **F1**. outer face and **F2.** inner face. **G**. *Chioneryx pygmaea.* **G1**. outer face and **G2**. inner face.

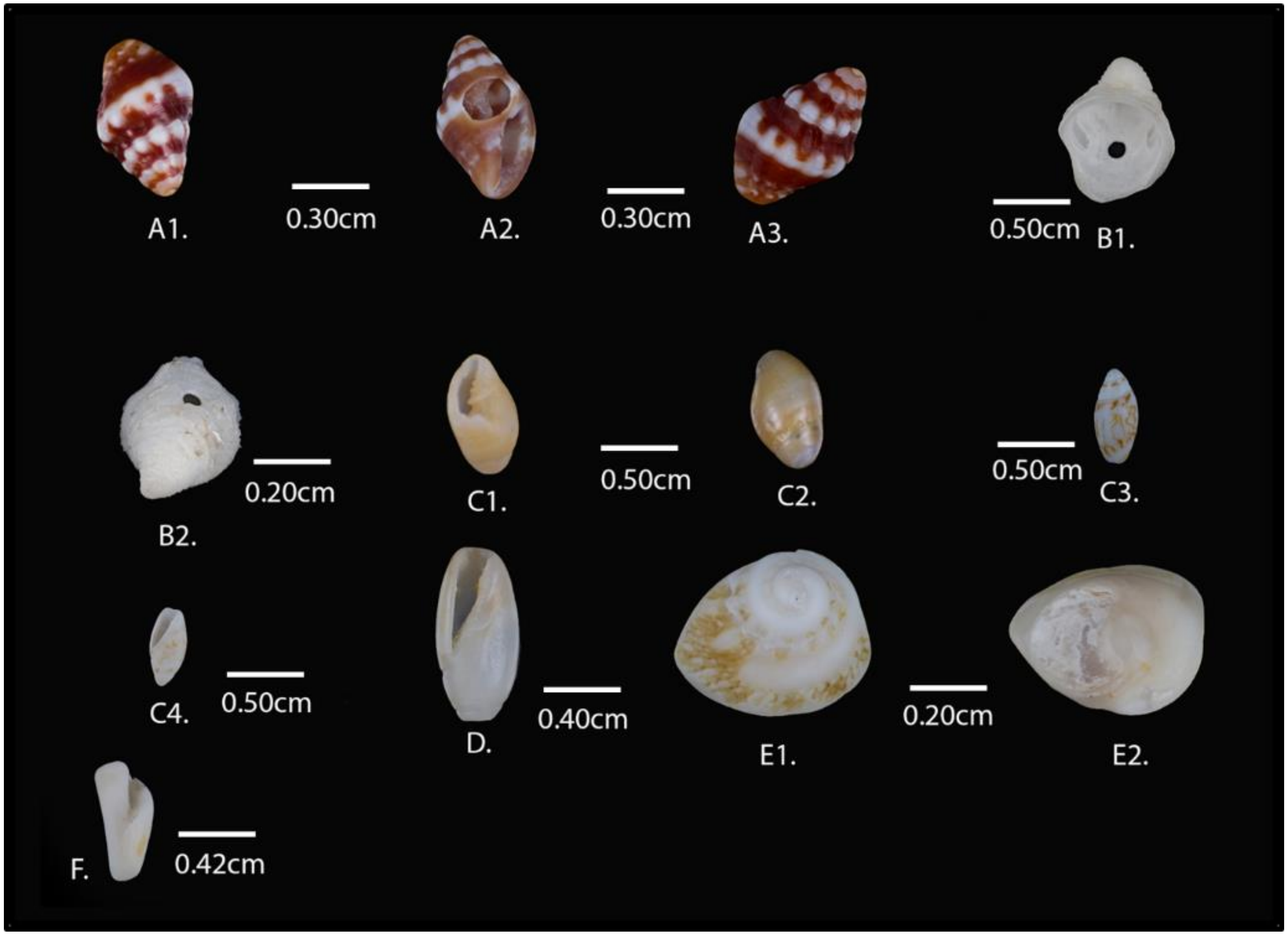

Plate Q13. Gastropods species found at Córcega beach, Rincón, in sampling 1 (August/September 2016). **A**. *Engina sp.* **A1**. outer face, **A2.** inner face and **A3**. outer face. **B**. *Hipponix subrufus* **B1**. inner face and **B2**. outer face. **C**. *Olivia sp.* **C1**. inner face, **C2**. outer face, **C3**. outer face and **C4**.inner face. **D**. *Olivella sp.* inner face. **E.** *Psilaxis krebsii*. **E1**. outer face and **E2**. inner face. **F**. *Cyphoma gibbosum.* (outer and inner face).

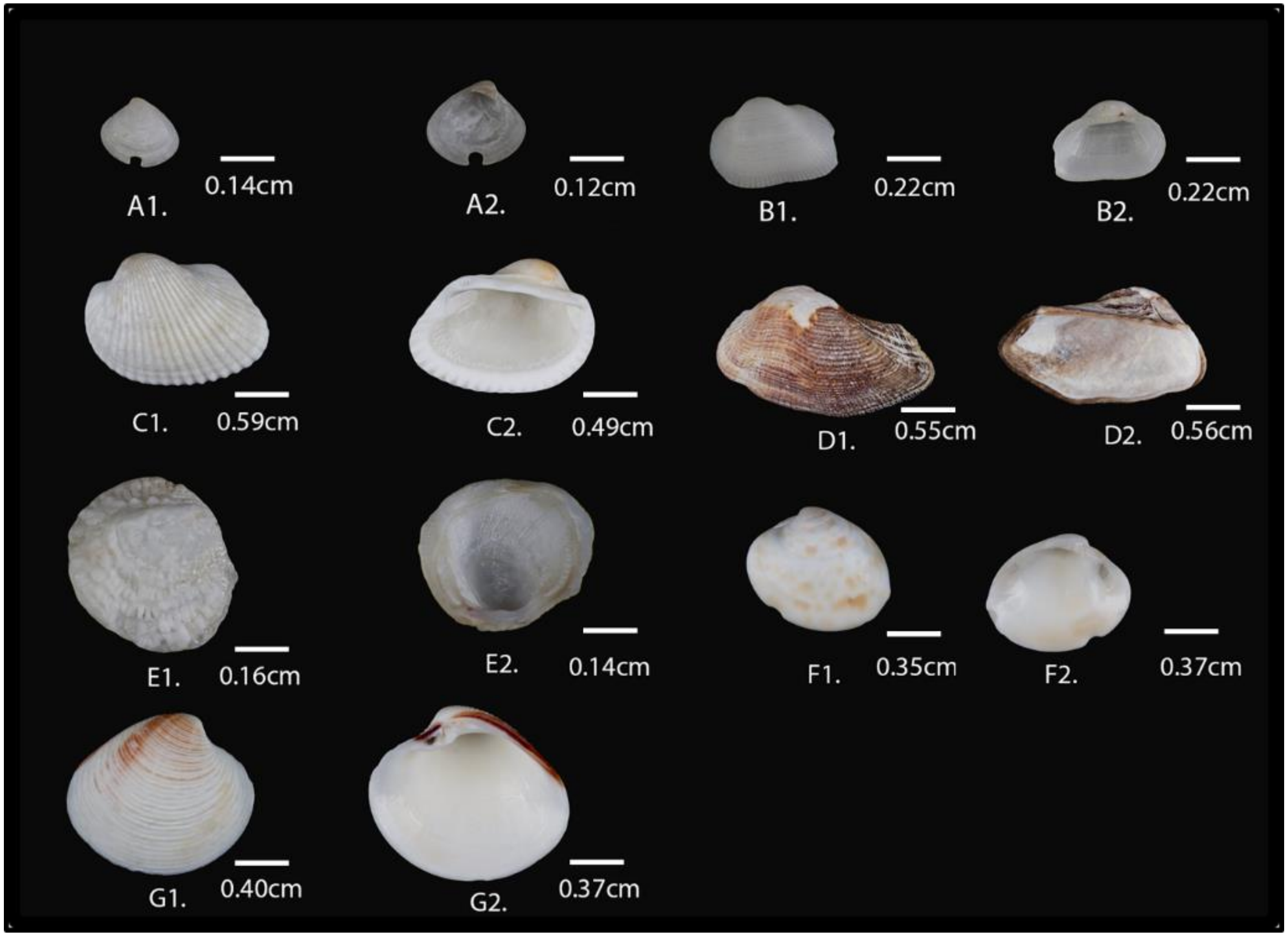

Plate Q14. Bivalves species found at Balneario Tres Hermanos beach, Añasco, in sampling 2 (October/ November 2016). **A**. *Acropsis sp.* **A1**. outer face and **A2**. inner face. **B**. *Yoldia limatula.* **B1**. outer face and **B2**. inner face. **C.** *Lunarca ovalis.* **C1**. outer face and **C2.** inner face. **D**. *Arca imbricata.* **D1**. outer face and **D2**. inner face. **E**. *Anomia simplex.* **E1**. outer face and **E2**. inner face. **F.** *Megapitaria maculata.* **F1.** outer face and **F2**. inner face. **G**. *Lamelliconcha circinata.* **G1**. outer face and **G2**. inner face.

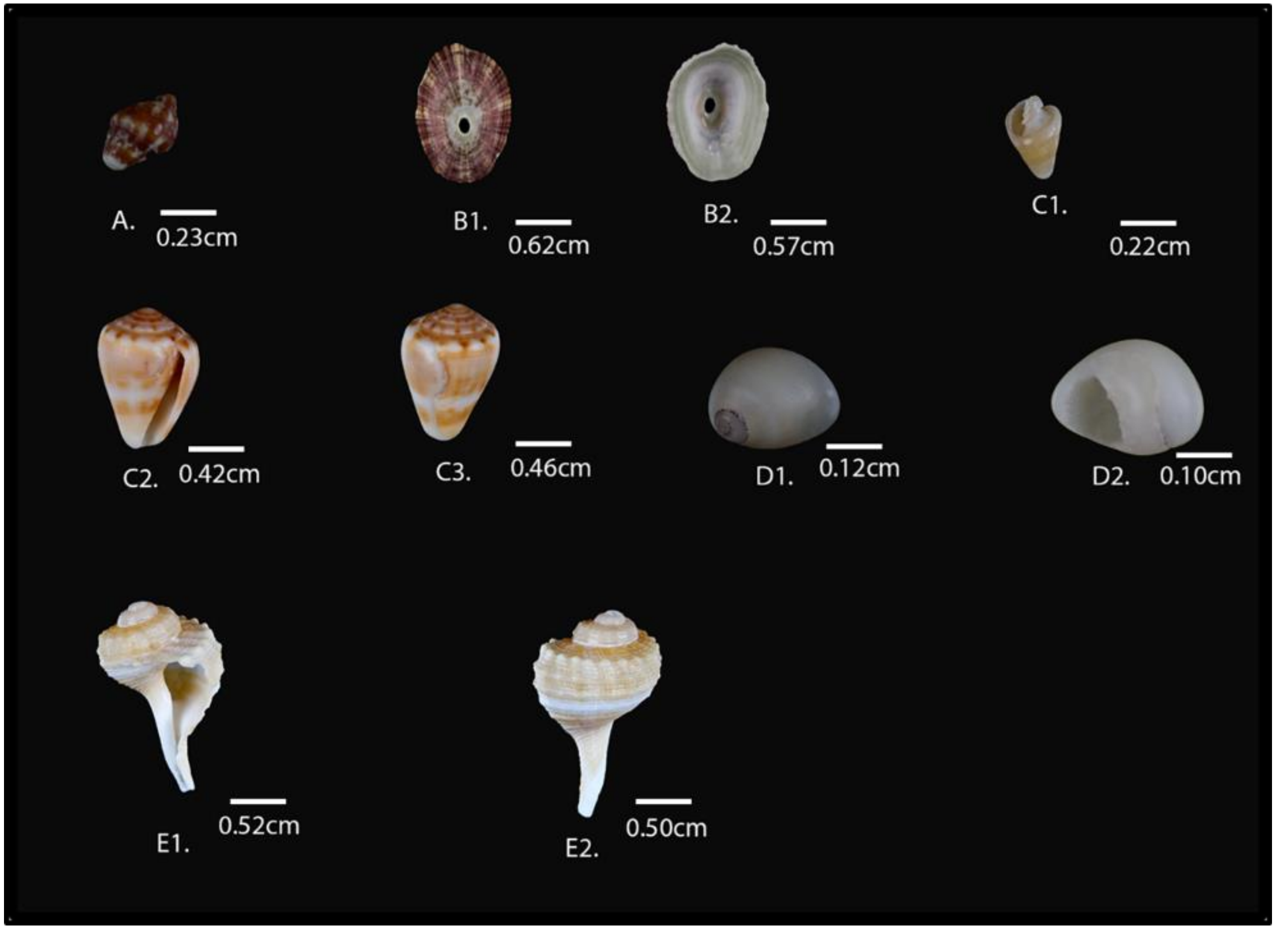

Plate Q15. Gastropods species found at Balneario Tres Hermanos beach, Añasco, in sampling 2 (October/ November 2016). **A.** *Engina sp.* outer face. **B**. *Diodora aspera.* **B1**. outer face and **B2**. inner face. **C1**. *Conus sp.* (outer and inner face), **C2.** *Conus daucus* inner face and **C3**. outer face. **D**. *Polinices sp*. **D1**. outer face and **D2**. inner face. **E**. *Busycon sp.* **E1**. inner face and **E2**. outer face.

Plate Q16. Bivalves species found at El Combate beach, Cabo Rojo, in sampling 2 (October/ November 2016). **A**. *Americardia media* **A1**. outer face and **A2**. inner face. **B**. *Anadara chemnitzii.* **B1**. outer face and **B2.** inner face. **C**. *Chione cancellata.* **C1**. outer face and **C2.** inner face. **D**. *Glycymeris pectinata*. **D1**. outer face and **D2**. inner face. **E**. *Anadara notabilis* **E1**. outer face and **E2**. inner face. **F.** *Trachycardium sp.* **F1**. outer face and **F2**. inner face.

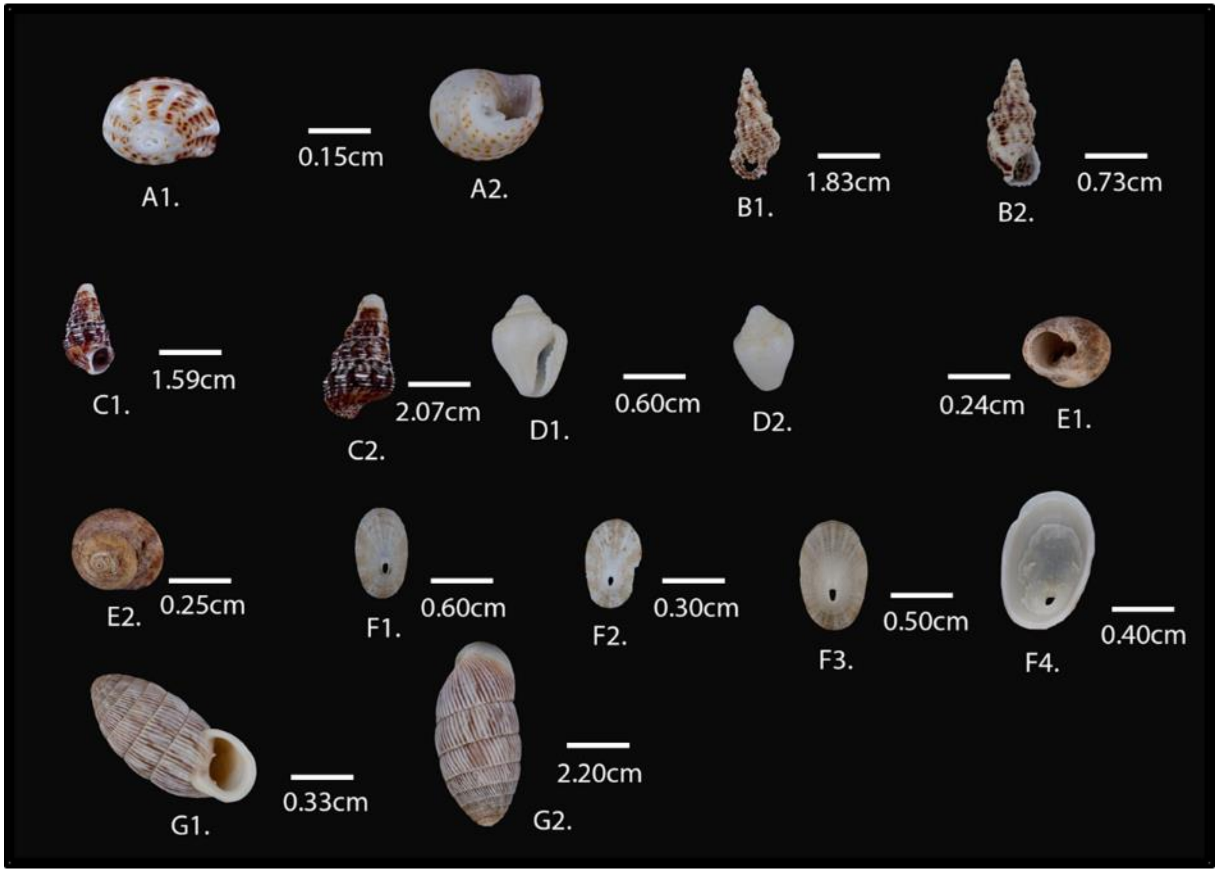

Plate Q17. Gastropods species found at El Combate beach, Cabo Rojo, in sampling 2 (October/ November 2016). **A**. *Architectonica nobilis.* **A1**. outer face and **A2**. inner face. **B**. *Lirobittium quadrifilatum.* **B1**. outer face and **B2**. inner face. **C**. *Cerithium cf eburneum.* **C1**. inner face and **C2**. outer face. **D**. *Columbella mercatoria*. **D1**. inner face and **D2**. outer face. E *Natica sp*. **E1.** inner face and **E2**. outer face. **F**. *Diodora cayensis.* **F1**. outer face, **F2.** *Diodora sp.* inner face, **F3**. *Diodora variegata* outer face, and **F4**. *Diodora variegata* inner face. **G**. *Cerion striatella.* **G1**. inner face and **G2**. outer face. [*Cerion striatella* is a terrestrial mollusk].

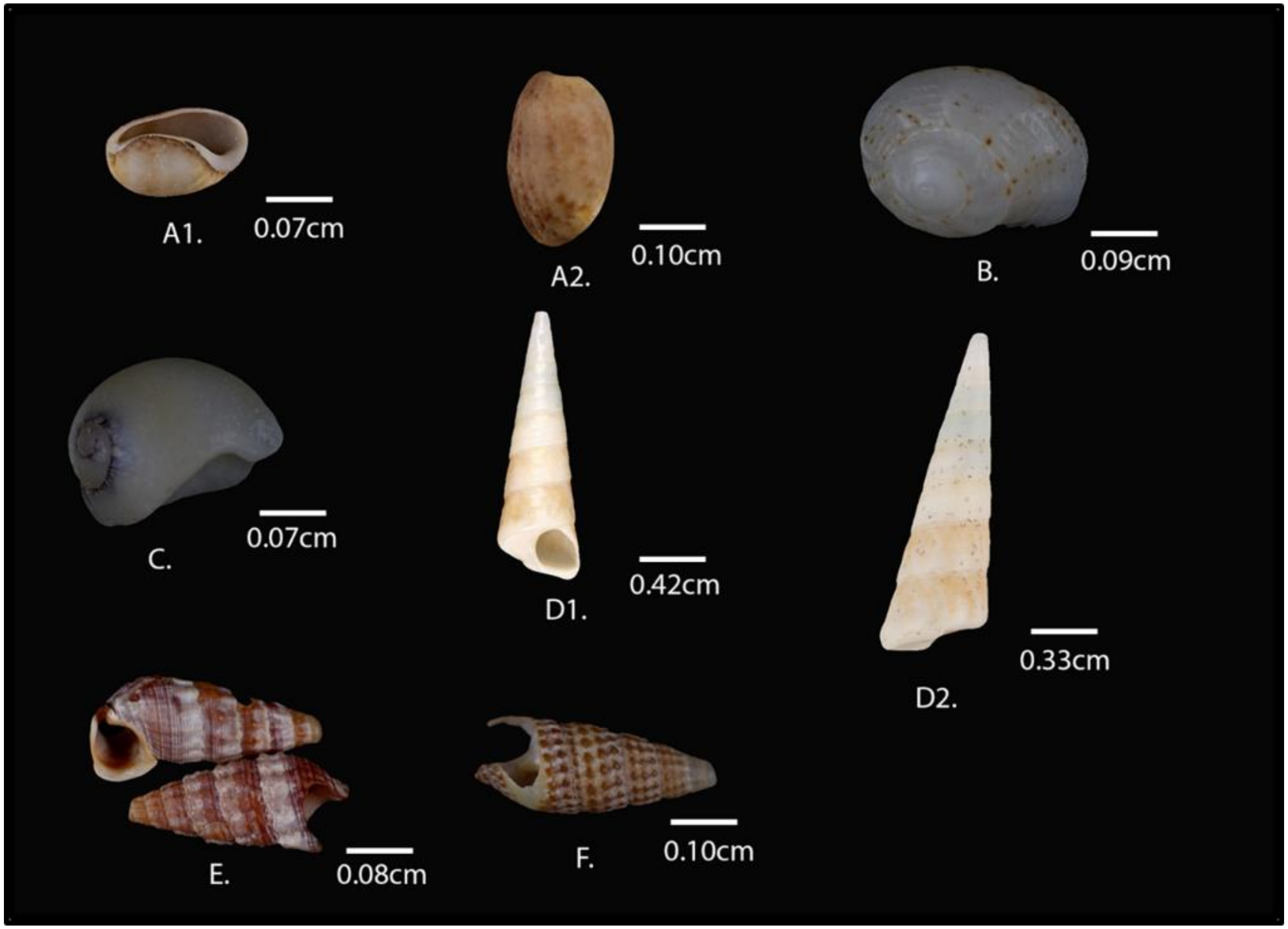

Plate Q18. Gastropods species found at El Combate beach, Cabo Rojo, in sampling 2 (October/ November 2016). **A**. *Olivella sp.* **A1**. inner face and **A2**. outer face. **B**. *Philippia sp.* outer face. **C.** *Smaragdia sp.* (inner and outer face). **D**. *Turitella variegata* **D1**. inner face and **D2**. outer face. **E**. *Lampanella minima.* (inner and outer face). **F**. *Cerithiopsis greeni* (inner and outer face).

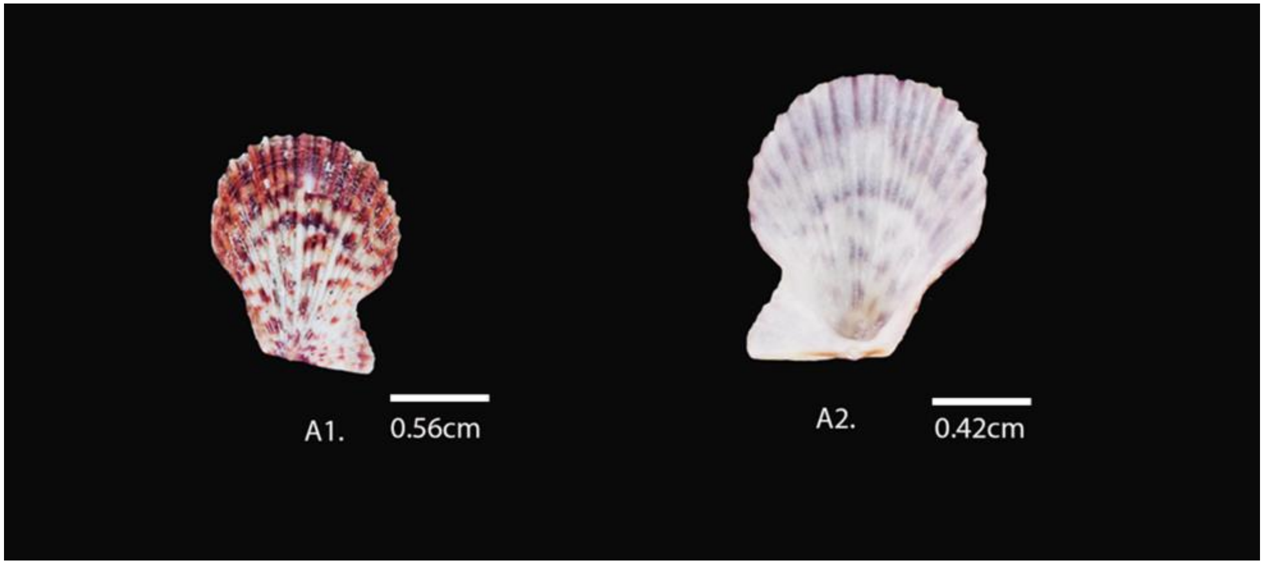

Plate Q19. Bivalves species found at Córcega beach, Rincón, in sampling 2 (October/ November 2016**). A**. *Caribachlamys ornata.* **A1**. outer face, and **A2**. inner face.

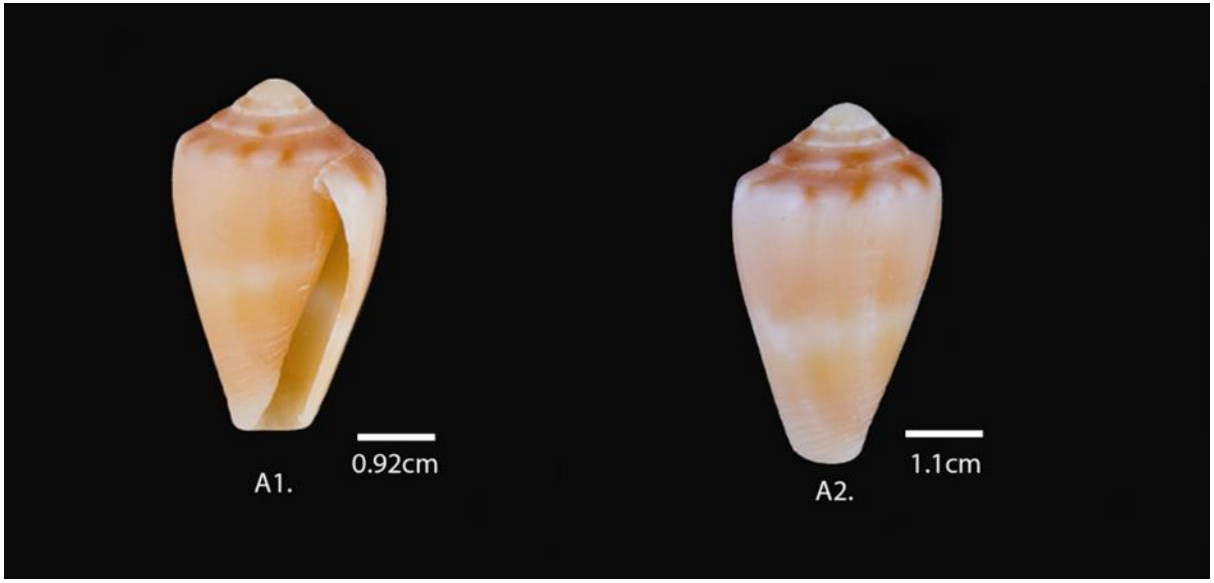

Plate Q20. Gastropods species found at Córcega beach, Rincón, in sampling 2 (October/ November 2016). **A.** *Conus daucus.* **A1**. inner face and **A2**. outer face.

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Estimada señorita Colón:

Proyecto de Investigación
Tortugas Marinas en el Área Oeste
Cabo Rojo, Mayagüez, Añasco y Rincón

El peticionario mencionado en epígrafe solicita al Departamento de Recursos Naturales y Ambientales (DRNA) una Autorización para llevar a cabo un Proyecto de Investigación, donde se propone recoger muestras de arena a 10 cm de profundidad con el propósito de estudiar los moluscos marinos que habitan en la Playa de Combate en Cabo Rojo, la Playa El Maní en Mayagüez, el Balneario hasta el Río Grande de Añasco y la Playa Córcega en Rincón.

Para llevar a cabo la actividad deberá coordinar las fechas y el lugar exacto con el personal del Proyecto de Tortugas Marinas del Área Oeste

El DRNA no tiene objeción a que se lleven a cabo los trabajos del proyecto de investigación propuesto. Sería de gran interés y utilidad para este Departamento que luego de finalizado el estudio comparta con nosotros el resultado del mismo. Siempre podrá contar con nosotros para éste y futuros proyectos en el litoral costero de Puerto Rico.

Cordialmente,

NVR

Nelson Velázquez Reyes
Secretario Auxiliar
Secretaria Auxiliar de Permisos

ARB/NVR/arb

P.O. Box 366147 San Juan Puerto Rico 00936
Tel: 787.999.2200 Fax: 787.999.2303
www.drna.gobierno.pr

DRNA

Plate Q21. Puerto Rico Department of Natural and Environmental Resources authorization permit (authorized by Nelson Velázquez Reyes in May 3rd, 2016).

Appendix R

Table R 1. Eigenvalues of Principal Component analysis from sampling 1 (August/September 2016). We only used PC1 and PC2 for this study.

```
                Inertia Rank
Total             1.801
Unconstrained     1.801   19
Inertia is variance

Eigenvalues for unconstrained axes:
   PC1    PC2    PC3    PC4    PC5    PC6    PC7    PC8
0.5177 0.4128 0.1799 0.1342 0.0873 0.0801 0.0751 0.0576
(Showed only 8 of all 19 unconstrained eigenvalues)
```

Table R2. Eigenvalues of Principal Component analysis from sampling 2 (October/November 2016). We only used PC1 and PC2 for this study.

```
                Inertia Rank
Total             2.772
Unconstrained     2.772   22
Inertia is variance

Eigenvalues for unconstrained axes:
   PC1    PC2    PC3    PC4    PC5    PC6    PC7    PC8
1.6289 0.2594 0.1451 0.1138 0.0988 0.0876 0.0675 0.0588
(Showed only 8 of all 22 unconstrained eigenvalues)
```