MACROBENTHIC BASELINE SURVEY OF THE PORT OF POINT GALEOTA, SOUTHEAST TRINIDAD

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ABSTRACT

Ports are usually associated with high anthropogenic activities and as such it is necessary to test the biological communities and the impact of these activities on them. Biological surveys can also provide valuable information such as assessment of environmental quality or the effects of climate change. This study provides a biological baseline to enable future monitoring and assessment of the port of Point Galeota. Galeota Port Phase 1 was opened on September 5th 2014. The port is of strategic importance given the increase in exploration activity off the East Coast. It comprises 529 m of quay wall accommodating 5 berths, which replaced the deteriorated facilities built in 1970. The macrobenthic fauna from within the Port of Galeota and surrounding south eastern peninsula were sampled once each in the dry (March) and wet (November) season of 2017. A total of 110 taxa were recorded with polychaetes being the most abundant taxa. Based on AZTI's Marine Biotic Index (AMBI) and the multivariate-AMBI (M-AMBI) (Borja *et al*., 2000), the Galeota Port was described as "slightly disturbed". The macrobenthic community was of "good" ecological status according to M-AMBI, with little seasonal variations in both AMBI and M-AMBI. Water and sediment quality indicated an absence of high levels of pollutants in the south eastern coast as well as within the port environment. These results are characteristic of those found in previous studies on Port Galeota.

Key words: Galeota Port, Macrobenthos, Benthic Baseline, Ecological Status

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1 INTRODUCTION

The demand for increased capacity of marine transportation vessels, facilities, and infrastructure is a global trend that is expected to continue in the future. As coastal population and development continue to grow, there is a concomitant increase in the demand for water transportation services and recreational opportunities. It is important to note that coastal areas under high developmental pressure are often located adjacent to productive and sensitive aquatic environments (NOAA, 2008).

The continued demand for coastal space today is likely attributed to the highly desirable aesthetic quality and recreational opportunities, including access to fishing, beaches, and boating. The expansion of port facilities, vessel operations, and commercial and recreational marinas can have adverse impacts on fishery habitat (Whitfield and Becker, 2014). The growth of the marine transportation industry is accompanied by land-use changes, including over-water or in-water construction, filling of aquatic habitat and wetlands, and increased maintenance activities (NOAA, 2008). Although some categories of habitat impacts resulting from activities related to port and marina construction and maintenance and vessel operations may be minimal and site specific, the cumulative effects of these activities over time can have substantial impacts on habitat (Todd *et al*., 2014; NOAA, 2008). Such impacts can be monitored once a Port Biological Baseline Survey (PBBS) has been conducted.

A PBBS is a scientific survey of the port's biological communities and ecology, focusing on the identity, distribution and abundance of non-native invasive species (NIS), some of which may prove invasive and ecologically damaging. Ideally, the survey will provide an inventory of the more easily observed biota occurring in the various habitats and substrates of the port environment, as well as some of the more cryptic species. Ports, however, are the most likely places for new marine species to arrive and settle, and therefore a logical place to initiate biological surveys. The type, abundance and distribution of organisms may change considerably due to the introduction of new species, so even where surveys have previously been carried out, it is important to monitor periodically (Awad *et al*., 2014).

It is necessary to periodically investigate and update the biological information collected at ports due to the nature of the environment and the associated high anthropogenic activity. The International Maritime Organisation (IMO) (Awad *et al*., 2014) recommends that PBBS be repeated at intervals of three to five years, and should form part of on-going environmental monitoring programmes. Biological and ecological information for port areas is generally scarce and seldom updated. This is due in part to the difficulties associated with scientific sampling in maritime and port areas, especially in light of security measures operating within most major ports (Awad *et al*., 2014).

Other valuable information can also be garnered through biological surveys such as assessments of environmental quality and harvestable marine resources, or studies of the effects of climate change. The repetition of PBBS, if possible, is valuable for the review of biological and ecological conditions and risk assessment of NIS. PBBS may prove to be an effective catalyst in building support for ratification and implementation of the Ballast Water Management (BWM) Convention and is essential for risk assessment and mitigation (Awad *et al*., 2014). In accordance with the Convention, risk assessments based on reliable biological data and on-going monitoring may be used to provide exemptions under Regulation A-4 for specific ships operating between specified ports and locations (e.g. those operating on low-risk routes).

Article 6 of the BWM Convention recommends States undertake scientific and technical research and monitoring such as "observation, measurement, sampling, evaluation and analysis of adverse impacts caused by such organisms and pathogens that have been identified to have been transferred through ships' ballast water" (Awad *et al*., 2014). This necessitates the collection of biological information on coastal and inland waters affected by shipping. Such assessments will record historical exposure to non-indigenous species introductions, aid in the detection of impacts on native species and communities exposed to such introductions and to monitor change over time. Long term monitoring programmes specifically for the identification of NIS are a crucial component of risk assessment for ballast water and NIS management. Although port surveys are not a specific requirement under the BWM Convention it is necessary that countries take steps to improve their information base on NIS, and where possible carry out PBBS in their major commercial ports. Conducting PBBS can:

i. Reveal the existing state of NIS infestation;

ii. Reinforce arguments for preserving the areas' natural biodiversity; and

iii. Support granting exemptions under Regulation A-4 of the BWM Convention, based on the IMO guidelines for risk assessment (G7)(Awad *et al*., 2014).

There are numerous challenges associated with port sampling, the chief among them being security measures within most major ports (Awad *et al*., 2014). This makes the collection of biological and ecological information in these areas scarce. Environments within port areas are generally distinct from coastal systems due to the large number of artificial structures, and the nature of the activities within ports, including, but not limited to shipping. Since ports have connectivity to the open coast, any biological changes occurring within the port may have effects on adjacent coastal ecosystems.

The construction of new ports and marinas typically involves the removal of sediments by dredging from intertidal and subtidal habitats in order to create navigational channels, turning basins, anchorages, and berthing docks for the size and types of vessels expected to use the facilities (Todd *et al*., 2014). For existing ports and marinas, dredging is generally conducted on a routine basis in order to maintain the required depths as sediment is transported and deposited into the channels basins, anchorages, and docks. Construction of ports and marinas can change physical and chemical habitat parameters such as tidal prism, depth, water temperature, salinity, wave energy, sediment transport, and current velocity (Todd *et al*., 2014; Johnson *et al*., 2008).

Alterations to physical characteristics of the coastal ecosystems can cause adverse effects to biological parameters, such as the composition, distribution, and abundance of shellfish and submerged aquatic vegetation. These changes can impact the distribution of nearshore habitats and affect aquatic food webs. Apart from removing native species due to coastal development, the introduction of non-native species to coastal environments through shipping vessels can also pose problems (Ricciardi, 2016). There is, therefore, an overlap between the areas generally managed by maritime and port authorities with those managed by environmental administrations. This

provides an opportunity as well as a justification for collaboration and resource-sharing between sectors important to the success of PBBS (Awad *et al*., 2014).

Non-native species, some of which are invasive, have been introduced to coastal areas through industrial shipping and recreational boating (Whitfield and Becker, 2014; Pertola *et al.*, 2006; Hanson *et al.*, 2003; Wilbur and Pentony 1999; Omori *et al.*, 1994). These introductions can be in the form of fouling organisms on the bottom of vessels as they are transported between water bodies or through the release of ballast water from large commercial vessels. Modern ships can carry 10 to 200 thousand tons of ballast water at a time and transport marine organisms across long distances in relatively short time periods (Hofer, 1998). This expeditious travel increases the risk that the organisms taken up in ballast water will be viable when introduced into a distant port or marina during de-ballasting (Awad *et al*., 2014; Pertola *et al*., 2006; Wilbur and Pentony 1999). Ship traffic can transport, in large numbers, non-native and invasive species of phytoplankton that can be harmful to native aquatic species (Awad *et al*., 2014; Pertola *et al.*, 2006).

Since the initial Cabinet decision to develop the (Phase 1) Galeota Port (State Enterprises Investment Programme, 2017), production sharing contracts were signed for ten (10) Blocks located on the east and south-east coasts of Trinidad. In light of the current and future expansion in exploration and development activities, the National Energy Corporation of Trinidad and Tobago engaged consultants to conduct a feasibility study on the expansion of port facilities at Galeota (Phase 2). The feasibility study determined, among other things, that with the leasing of the new exploration blocks, larger workboats and sea-going vessels would likely be required. Given the anticipated demand for port services, it was recommended to increase the berth space flexibility and draft depth to accommodate larger vessels (NGC, 2015). Such port expansion could lead to significant impacts on the local benthic environment, which has been shown to have a moderate level of diversity (Gobin 2008; 2006; Coastal Dynamics Limited, 2004; EPAS Consultant Limited, 2004; IMA, 1996).

Ecological studies have been conducted off the south-eastern coast of Trinidad, notably by the IMA (IMA, 2006). That study found 129 and 113 distinct benthic species during the wet and dry season sampling periods, respectively. The benthos in the area were shown to have moderately

diverse fauna through mulitvariate analysis with only slight evidence of disturbance due to petroleum related activities (IMA, 2006). Noteworthy species was that of *Ampelisca paria* (Barnard and Agard, 1986), an endemic amphipod to Trinidad. The stations sampled during the current study however, were located some distance away from the port, and predated the expansion of the port.

Surveys have also been conducted with respect to drilling occurring off the south-eastern coast of Trinidad. British Petroleum Trinidad and Tobago (BPTT) commissioned a comprehensive baseline macrofaunal survey of the benthic community in 2004 (Coastal Dynamics Limited, 2004). The fauna comprised a number of species which may be new to science as well as some which may be the first scientific record for Trinidad and Tobago and as such were not immediately recognised.

An environmental impact assessment (EIA) conducted on the offshore Galeota block reported that the benthic macroinfauna was dominated by polychaetes (58%), while 34% accounted for arthropods and 4% molluscs (Coastal Dynamics Limited, 2013). The percentage representation by each faunal group is typical for soft bottom sediments along the south eastern coast of Trinidad (Gobin 2006, 2008; Coastal Dynamics Limited, 2004; EPAS Consultant Limited, 2004; IMA, 1996), with a similar prevalence of polychaetes observed in 2011 (Mangal, 2011). The expansion and increased activity at the Point Galeota Port can alter the structure of this benthic community with the introduction of non-native organisms having the potential to become invasive with negative consequences.

In earlier studies, the benthic communities within the immediate vicinity of the Port were not sampled, and therefore benthic sampling remains essential in ascertaining the status of invasive organisms in Trinidad and Tobago's coastal environment.

In the context of BWM, a PBBS has 4 specific purposes:

i) to inform port authorities and lead agencies responsible for BWM about the current position with respect to NIS and cryptogenic species within the port and surrounding areas, including those that may have been introduced by shipping;

ii) to prepare an inventory of aquatic plants and animals inhabiting the port and adjacent areas including their distribution and relative abundance;

iii) to guide the development of BWM strategies and measures applicable to the port and visiting ships; and

iv) to provide a baseline of biological data against which future changes in aquatic communities, including NIS and AIS, can be measured (Awad *et al*., 2014).

The purpose of this survey is to gather information on marine biodiversity within the port, with a particular emphasis on establishing the presence of non-indigenous species. Information collected can then be used as a baseline for future monitoring studies as port activity increases.

2 METHODOLOGY

2.1 SITE DESCRIPTION

Galeota Port Phase 1 was opened on September 5th 2014. It comprises 529 m of quay wall accommodating five berths, which replaced the deteriorated facilities built in 1970. The existing facilities were obsolete and not capable of supporting the requirements of the various oil and gas companies operating the offshore platforms. The new facilities will support the bpTT to expand the level of service to offshore oil and gas exploration activities. Additionally, it will provide a permanent facility for the Trinidad and Tobago Coast Guard, as well as a fishing port for the local residents. Port of Galeota typical vessel activity is mainly that of droghers i.e. vessels operating within local jurisdictions (Personal communication, National Energy Company). There have been three international vessel calls with two originating in the United States of America and one from China passing through the Panama Canal (Personal communication, National Energy Company).

Nine sampling stations were established along the Galeota Port and along the south coast leading in to the Port (Figure 1). Coordinates of the stations were recorded using a hand held GPS.

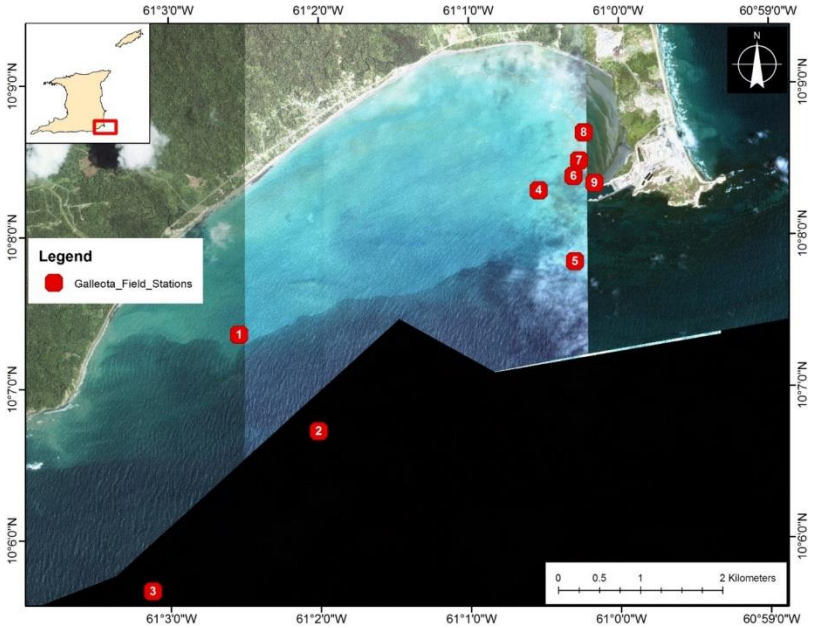

FIGURE 1: SAMPLE SITES AT GALEOTA PORT AND ALONG THE SOUTH COAST OF TRINIDAD

2.2 SAMPLE METHODS

Physical parameters

Temperature, salinity, dissolved oxygen concentration, and pH were measured at all sample locations using a YSI multi-parameter meter during each sampling period. Nitrate and nitrite concentrations in the water were determined using standard methods by Eaton *et al*., 2005. Ammonium and phosphate were determined using methods described in Grasshoff *et al*., (1983).

Benthic/ Epibenthic Community

Sampling was conducted twice in 2017; once in the wet season and once in the dry season. At each of the nine stations, six replicate grabs were taken using a 0.25m^2 Van veen grab. This was the number of replicates possible given sea conditions and time constraints. Grab samples were sieved using 0.5mm sieve buckets. Benthic macrofauna were washed from the sieve buckets into containers where macrofauna were euthanized using a 0.05% alcohol mixture. After a period of 24 hours, samples were fixed using 5% formalin. After collection, samples were sieved on nested meshes of 0.5 mm and 63 µm in the laboratory. Macrophytes remaining on the 0.5mm sieve were carefully washed over the mesh to remove associated macrofauna.

All macrophytes and fauna within the sample were carefully and completely removed. All macrofauna was sorted and identified to the lowest possible taxonomic level using the following keys: The polychaete worms (Fauchald, 1976); annelida: oligochaeta, including branchiobdellidae (Brinkhurst and Gelder, 2001), intertidal and shallow water amphipods (Pazríos *et al*., 2013). The animals retained once sorted, were then transferred into 70% ethanol for storage.

Sediment

Sediment samples were collected using a 0.25m^2 Van Veen grab. They were dried at 60^oC for 48 hours, then sieved to obtain the <180µm size fraction, in which the dependence of metal content on surface area was removed (Hawkes and Webb, 1962; Oliver, 1973). Samples for total recoverable metals were prepared using microwave assisted acid digestion according to a modified version of the USEPA Method 3051A (USEPA, 2007). 10 ml of concentrated HNO_3 was added to

1g of sediment and allowed to pre-digest at room temperature for 30 minutes or until the initial reaction subsided. The mixture was then heated up to 175^{o}C over a 30 minute period and held at this temperature for 4.5 minutes using the CEM Microwave Accelerated Reaction System (MARS) 6. Samples were allowed to cool and then centrifuged at 5000 rpm for 20 minutes. Samples were decanted and made up to a fixed volume depending on the volumetric ware.

Analysis was performed with the Shimadzu AA-7000 Atomic Absorption Spectrometer using Flame Atomic Absorption Spectrometry with deuterium background correction. Detection limits for each metal were: Cd: 0.5 $\mu g\ g^{-1}$, Cr: 5.0 $\mu g\ g^{-1}$, Cu: 2.5 $\mu g\ g^{-1}$, Fe: 5.0 $\mu g\ g^{-1}$, Pb: 0.5 $\mu g\ g^{-1}$, Ni: 0.5 $\mu g\ g^{-1}$, Zn: 0.6 $\mu g\ g^{-1}$.

2.3 Analysis of Results

Benthic diversity (Shannon-Wiener Index), richness, abundance, Multidimensional Scaling (MDS) and Principal Component Analysis (PCA) were performed using PRIMER 6. Microsoft Excel evaluated significant difference from each group via Kruskal-Wallis one-way non-parametric ANOVA (level of significance 0.05) and Statistical Packages for the Social Sciences (SPSS) 20 evaluated nonparametric correlation method (Kendall's tau) to obtain the correlation coefficient among physicochemical parameters in water and sediment. Primer 6 software was used to assess.

The health status of the benthic communities was assessed with AZTI Marine Biotic Index (AMBI), BI and M-AMBI. These indices were designed to classify the ecological quality of coastal communities according to the response of soft bottom macrobenthic invertebrates to variations in water quality. Macroinvertebrates are classed according to four different ecological groups. Ecological Groups I and II are classed as sensitive species, Ecological Group III are species tolerant to pollution and Ecological Group IV as opportunistic species.

3 RESULTS

3.1 SPECIES COMPOSITION

A total of 1713 organisms belonging to 109 different species were recorded. Five hundred and sixty two (562) individuals comprising thirty-six (36) different species of Annelida were recorded, and this accounted for 27% of all individual organisms found (Figure 2). Sixteen (16) different species of Mollusca were recorded, accounting for 6% of all organisms found (Figure 2). Thirty-one (31) species of Amphipods were found, accounting for 50% of all organism recorded and four (4) species of Tanaidacea were found accounting for 4% of all individual recorded (Figure 2). Two (2) species of Cumaceans accounting for 4% of all individuals recorded and Nemertea accounted for 4% of all organisms recorded (Figure 2). All other organisms, comprising of Isopoda, Decapoda, Copepoda, Chordata, Ophiuroidea, Cnidaria, Sipuncula and Mysida accounted for the remaining 5% of organisms (Figure 2).

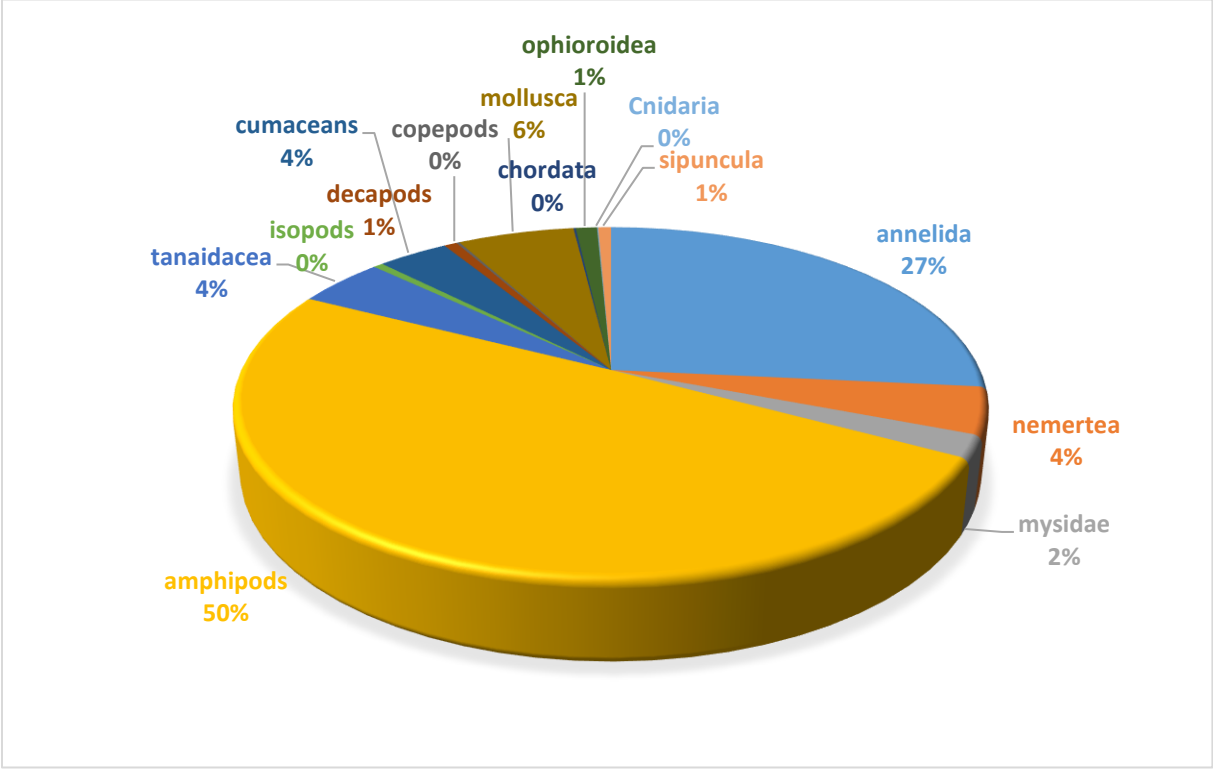

FIGURE 2: TOTAL PERCENTAGES OF ORGANISMS FOUND AT THE GALEOTA PORT FOR THE WET AND DRY SEASONS 2017

Amphipods were in higher abundance than polychaetes for the 9 stations in the dry season. They accounted for 61% of all species found with a total abundance of 775 individuals (Table 1).

TABLE 1: ABUNDANCES FOR THE TOP TEN PHYLA FOR THE DRY AND WET SEASONS

Species	Dry	Wet	Total
Amphipods	775	123	898
Polychaetes	294	186	480
Non-segmented worms	7	78	90
Tanaidacea	40	42	82
Gastropods	48	30	78
Cumaceans	31	35	66
Mysidae	24	13	37
Bivalves	22	9	31
Ophioroidea	9	11	20
Decapods	8	4	12

The majority of amphipods were found at Station 5 (632 individuals) belonging to the species *Grandidierella halophilus* (Wongkamhaeng *et al*., 2012) (Table 2). The second most abundant taxa collected in the dry season were polychaetes (23%, 294 individuals) (Table 1), followed by gastropods (4%, 48 individuals) (Table 1). The organisms that were most common to all stations during the dry season were the polychaete-*Goniada maculata*, (Örsted, 1843) the cumacean-*Leptochelia sp.*, and the amphipod- *Parhyale hawaiiensis*, (Dana, 1853) all of which were found at six of the nine sampled stations.

The composition changed in terms of abundance during the wet season. Polychaetes accounted for 34% (186 individuals) (Table 1) of all species found, followed by amphipods (23%, 123 individuals) (Figure 2, Table 1) and non-segmented worms (15%, 78 individuals) (Figure 2, Table 1). The spionid worm *Prionospio cirrifera* (Wirén, 1883) was the most abundant (79 individuals) polychaete collected (Table 2). Station 5 recorded the highest number of species (21), however the largest number of organisms was recorded at Station 3 (134 individuals). *G. maculata* was once again the most common species, found at all nine sample stations along with the mysid, *Siriella sp.* which was found at eight of the nine sampled stations. The polychaete, *P. cirrfera* was found at seven of the nine sampled stations.

Based on the number of individuals across both seasons, the top ten most abundant species were - *Grandidierela sp., G. maculata, P. cirrifera, Armandia sp 2. Prionospio sp.,* Nemertea, *Olivella petiolita* (Duclos, 1835), *Leodamus sp., Bemlos spinicarpus* (Pearse, 1912), and *Cumella pygmaea* (Sars, 1865) (Figure 2). Large numbers of *Grandierella sp.* were found at Station 5 during the dry season hence the reason for its high numbers, but poor distribution. Similarly, with the exception of *G.maculata* and *P. cirrifera* all of the species with the highest number of individuals showed large numbers at a few stations, but were poorly distributed throughout the sampling sites. Amphipods showed a marked decrease in numbers from the dry season to wet season (775 to 123 individuals). This was due mostly to an unusually high presence of *Grandiderella sp.* found at Station 5 during the dry season which accounted for 632 individuals (Table 2). The highest number of species (26) was found at Station 3 during the dry season. The largest amount of organisms was found at Station 9 during the dry season; 744 individuals were collected.

Abundance

This value represents an enumeration of all the individuals in the sample. This value contributes to the measurement of productivity in a system. The total abundance varies between 24 and 744 individuals (Figure 3). The highest abundance was recorded at Station 5 during the dry season (744) (Figure 3). The lowest abundance was recorded at Station 9 during the wet season (24) (Figure 3). A significant difference was observed (ANOVA, $p > 0.05$) between stations for the wet and dry seasons.

Number of Species

Number of species is the simplest measure of diversity. This value represents an enumeration of all the species in a sample. This value also contributes to the measurement of productivity in a system. Number of species varies between 7 and 21 for each station across both seasons (Figure 4). The highest number of species was recorded at Station 6 during the wet season (31) (Figure 4). The lowest number of species was recorded at Station 8 during the wet season (8) (Figure 4).
A significant difference was observed (ANOVA, $p > 0.05$) between stations for the wet and dry seasons.

TABLE 2: NUMBER OF SPECIES, ABUNDANCE, RICHNESS, DIVERSITY AND DISTRIBUTION OF MACROBENTHIC ORGANISMS COLLECTED IN THE DRY AND WET SEASONS OF 2017

Station Number	*Dry*									*Wet*									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Species																			**Total**
Phylum																			
Annelida																			
Polychaeta																			
Eunicida																			
Arabella sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Dorvillea sp.	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**5**
Eunice sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Lumbrineries latreilli	2	0	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	**6**
Lumbrineries sp.	0	0	1	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	**4**
Diopatra cuprea	0	0	0	0	2	1	0	1	0	0	0	3	0	0	3	0	1	0	**11**
Nothria conchylega	15	1	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	**19**
No Order																			
Aricidea sp.	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	**3**
Armandia maculata	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	**3**
Armandia sp.	0	0	0	8	0	0	0	0	0	0	0	0	11	0	0	0	0	0	**19**
Cossura sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Euclymene sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Leodamus sp.	0	0	0	29	0	0	0	0	0	0	0	0	12	0	0	0	0	1	**42**
Magelona sp.	1	1	0	0	0	1	1	0	1	1	3	1	0	7	1	0	0	0	**18**
Maldane sp.	0	2	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	**5**
Notomastus latericeus	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Notomastus sp.	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	3	**5**
Sabellida																			
Branchiomma sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Phyllodocida																			
Ceratonereis sp 1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	**2**
Glycera sp1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Glycera sp2.	0	0	0	0	10	0	1	0	5	0	0	0	1	0	0	0	0	4	**21**
Goniada emerita	0	1	6	0	1	0	0	0	0	0	0	0	11	0	0	0	0	0	**19**
Goniada japonica	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Goniada Maculata	6	6	1	6	0	2	2	11	10	0	0	12	14	1	7	5	8	3	**94**
Goniada sp.	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	9	**11**
Nereis lamellosa	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	**2**
Nereis sp.	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**2**

Station Number	*Dry*									*Wet*									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Species																			**Total**
Phyllodoce sp.	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	**2**
Sigambra tentaculata	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Spionida																			
Pisionidens sp.	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	**3**
Prionospia cirrifera	1	0	0	0	0	0	5	14	21	0	0	1	3	12	2	1	24	0	**84**
Prionospio sp.	0	0	0	0	0	0	0	65	11	0	0	0	1	1	0	0	0	0	**78**
Terrebellida																			
Raricirrus sp.	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**7**
Sabellida																			
Sabellidae sp 1		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**1**
Serpula sp.	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**5**
Nemertea		0	1	0	0	0	0	0	0	6	1	0	0	69	0	0	0	0	**77**
Anopla																			
Lineidae																			
Micrura sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Mysida																			
Siriella sp.	4	0	0	0	0	13	4	3	0	0	0	0	0	1	3	7	1	1	**37**
Amphipoda																			
Bamarooka tropicalis	0	0	1	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	**5**
Ampelisca sp 2.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	**7**
Ampelisca sp 1.	0	1	0	0	0	0	0	0	0	0	1	0	0	0	7	0	0	0	**9**
Apolochus neapolitanus	1	0	0	0	0	3	0	0	0	0	0	0	0	0	9	0	0	0	**13**
Azotostoma sp	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Bemlos sp.	0	0	1	0	0	4	0	0	0	0	0	0	0	6	8	0	0	0	**19**
Bemlos spinicarpus	0	0	2	1	27	0	0	0	0	0	0	0	1	2	9	0	0	0	**42**
Globosolembos sp.	0	0	0	1	1	1	0	0	0	0	0	0	4	0	0	0	0	0	**7**
Grandidierela halophilus	0	0	0	0	632	0	0	0	0	0	0	0	0	1	0	0	0	0	**633**
Grandidierella bonnieroides	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	**12**
Grandidierella rhizophorae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Lembos unifasciatus reductus	0	0	0	0	0	3	0	0	0	0	0	0	0	0	17	0	0	0	**20**
Microdeutopus sp.	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	**15**
Paramicrodeutopus myersi	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**2**
Birubius banksi	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	**2**

Station Number	*Dry*									*Wet*									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Species																			**Total**
Birubius sp1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Birubius sp2.	0	0	0	0	0	13	3	0	0	0	0	0	0	0	7	9	0	0	**32**
Caprella sp.	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**4**
Deutella incerta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	**2**
Cyproidea sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	0	0	**8**
Elasmopus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	**4**
Eudevenopus hondurans	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Hyalella sp.	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Leucothoe sp.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Melita sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	**2**
Nototropis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**
Paraelasmopus sp.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Parelasmopus suensis	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**1**
Parhyale hawaiiensis	0	1	1	1	26	0	0	0	0	0	0	3	0	2	0	0	0	0	**34**
Pontoporeia	5	0	1	0	0	0	0	0	1	0	6	0	0	0	0	0	0	0	**13**
Shoemakerella banardi	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	**2**
Tanaidacea																			
Chondrochelia dubia	0	0	0	0	0	13	0	0	0	0	0	0	0	0	1	4	0	0	**18**
Leptochelia sp.	0	7	1	1	0	13	0	0	0	5	2	0	0	0	0	0	0	0	**29**
Tanaidacea	0	0	0	0	0	5	0	0	0	0	0	0	0	0	22	0	0	0	**27**
Tanapsuedes gutui	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	**8**
	0	7	1	1	0	31	0	0	0	5	2	0	0	0	31	4	0	0	**82**
Isopoda																			
Aegidae	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Cirolana sp.	2	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0	**6**
Flattened isopod	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Cumacea																			
Cumella pygmaea	0	1	0	0	0	3	7	8	9	0	5	0	0	4	2	0	3	0	**42**
Cumella sp.	2	0	0	1	0	0	0	0	0	0	0	20	1	0	0	0	0	0	**24**
Decapoda	0																		
Brachyura		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**1**
Penaeus notialis	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Pinnixia sp	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Sesarma sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**

Station Number	*Dry*									*Wet*									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Species																			**Total**
Cancer. Sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Gytoplax sp.	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Pagurus sp.	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	**3**
Copepoda																			
Harpacticoid copepod	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	**3**
Mollusca																			
Bivalvia																			
Chione cancellata	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Chione sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Lucinidae	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Cymatoica hendersoni	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Strigilla carnaria	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0	0	**4**
Tellina radiata	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	**4**
Trannsenella	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**6**
Nuculana acuta	0	3	0	0	0	0	0	0	0	0	0	0	0	4	3	0	0	0	**10**
Unknown bivalve	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Gastropoda																			
Syrnola producta	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	**6**
Natica canrena	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Olivella petiolita	0	0	0	24	0	0	3	4	6	0	2	3	8	0	0	0	6	0	**56**
Cumingia tellinoides	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Diplodonta punctata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Donax sp.	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	8	0	0	**12**
Persicula imbricata	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**1**
Chordata																			
Gymnothorax sp	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Ophioblennius sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Clitellata																			
Oligochaeta	0	0	0	1	0	4	0	0	0	0	0	0	2	5	0	0	3	0	**15**
Ophioroidea																			

Station Number	*Dry*									*Wet*									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Species																			**Total**
Ophiophragmus filograneus	0	0	2	1	0	2	0	0	0	4	4	6	0	0	1	0	0	0	**20**
Cnidaria																			
Renilla amesthystina	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Sipuncula	0	0	4	0	0	3	0	0	0	1	0	0	0	1	2	1	0	0	**12**
No. of species	**17**	**16**	**26**	**18**	**19**	**25**	**12**	**9**	**11**	**12**	**11**	**11**	**13**	**21**	**31**	**10**	**7**	**9**	
Abundance	**47**	**38**	**57**	**87**	**744**	**129**	**32**	**109**	**69**	**32**	**32**	**51**	**71**	**128**	**165**	**45**	**46**	**24**	**1906**
Richness	**4.09**	**4.37**	**6.21**	**3.82**	**2.72**	**5.25**	**3.17**	**1.70**	**2.36**	**3.38**	**2.94**	**2.53**	**2.81**	**4.12**	**6.12**	**2.42**	**1.58**	**2.52**	
Diversity	**2.37**	**2.45**	**2.98**	**2.00**	**0.75**	**2.78**	**2.26**	**1.37**	**1.98**	**2.19**	**2.20**	**1.83**	**2.18**	**1.91**	**2.96**	**2.03**	**1.43**	**1.85**	

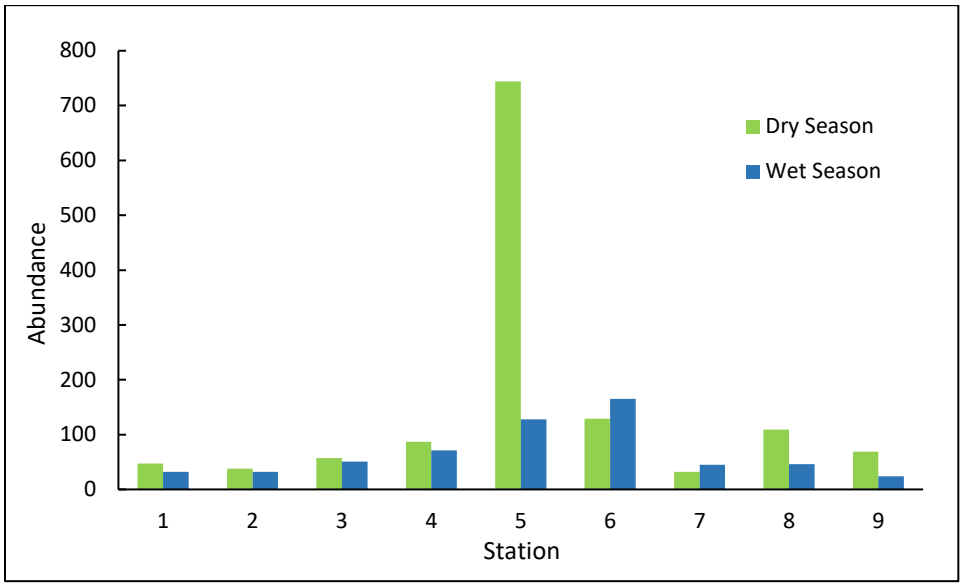

FIGURE 3: TOTAL ABUNDANCES FOR THE WET AND DRY SEASONS AT PORT GALEOTA

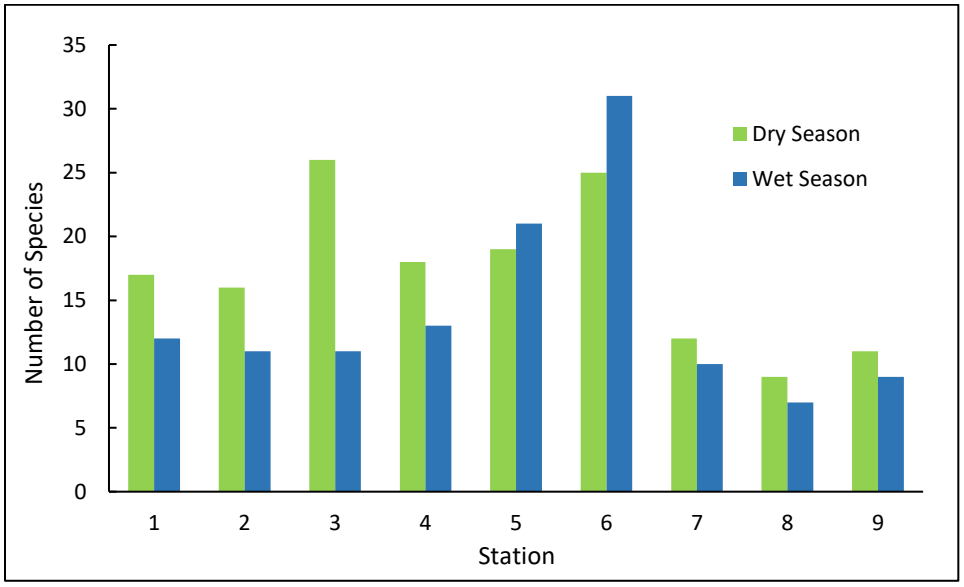

FIGURE 4: TOTAL NUMBER OF SPECIES FOR THE WET AND DRY SEASONS AT PORT GALEOTA

Diversity

The Shannon Weiner Diversity Index is commonly used to characterise species diversity in a community taking into account abundance and species evenness present. Shannon's Diversity Index ranged from 0.75 at Station 5 in the dry season to 2.97 at Station 3 also in the dry season

(Figure 5). A significant difference was observed (ANOVA, $p > 0.05$) between stations for the wet and dry seasons.

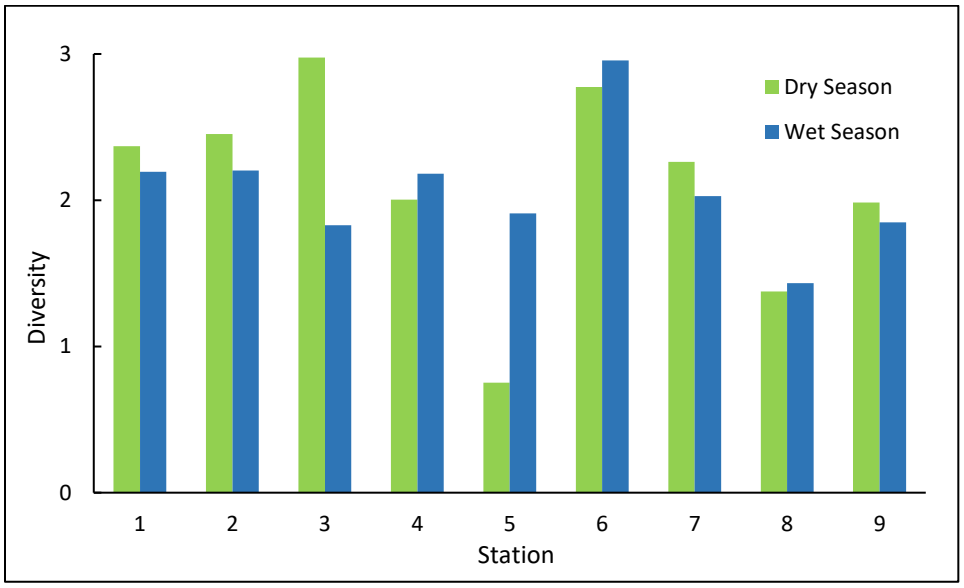

FIGURE 5: SPECIES DIVERSITY FOR THE WET AND DRY SEASONS AT PORT GALEOTA

AMBI

Based on the AMBI model (Borja *et al*., 2012), the pollution levels showed no extreme variations among stations (Table 3). In general, Port Galeota can be described as a "Slightly polluted" port (BI: 1.67. AMBI: 1.34, M-AMBI: 0.67) as all stations with the exception of Stations 3 for the wet season, and Stations 4 and 9 in the dry season were slightly disturbed.

All stations with the exception of Station 2 were dominated by Ecological Groups I and II (sensitive species). Station 2 was dominated by Ecological Group III (tolerant to pollution). For the wet season, Stations 5, 7, 8 and 9 showed a decrease in species abundance while all other stations showed an increase (Table 3). Shannon's Diversity ranged from 1.37 at Station 6 to 2.96 at Station 3 (Table 3). Species richness ranged from 1.57 at Station 7 to 6.12 at Station 3 (Table 3). AMBI values were once again consistent for the wet season. Station 3 was classified as "Undisturbed" while all other stations were classified as "Slightly disturbed". In the wet season, there was no change to the disturbance classification for Port Galeota (BI: 1.89, AMBI: 2.08, M-AMBI: 0.61) as most stations once again fell into the "Slightly disturbed" classification. With the exception of Station 1, which was dominated by Ecological Group III and Stations 7 and 8 which

were dominated by Ecological group IV (opportunistic species), all other stations were dominated by Ecological Groups I and II.

TABLE 3: ECOLOGICAL INDICES USED TO ASSESS POLLUTION LEVELS BASED ON THE MACROBENTHIC COMMUNITY

Station	Abundance	Diversity	Richness	BI	AMBI	Disturbance Classification	M-AMBI	Status
dry season								
1	52	2.37	4.09	2	1.77	Slightly disturbed	0.68	Good
2	27	2.19	3.38	2	2.10	Slightly disturbed	0.59	Good
3	31	2.45	4.37	2	1.60	Slightly disturbed	0.71	Good
4	30	2.20	2.94	1	0.98	Undisturbed	0.65	Good
5	56	2.97	6.21	2	1.43	Slightly disturbed	0.85	High
6	51	1.83	2.53	2	1.30	Slightly disturbed	0.61	Good
7	86	2.00	3.82	2	1.35	Slightly disturbed	0.68	Good
8	71	2.18	2.81	2	1.50	Slightly disturbed	0.64	Good
9	744	0.75	2.72	0	0.01	Undisturbed	0.63	Good
wet season								
1	128	1.91	4.12	2	2.72	Slightly disturbed	0.61	Good
2	98	2.77	5.25	2	2.01	Slightly disturbed	0.79	High
3	134	2.96	6.12	1	1.12	Undisturbed	0.93	High
4	32	2.26	3.17	2	1.71	Slightly disturbed	0.62	Good
5	41	2.03	2.42	2	1.31	Slightly disturbed	0.61	Good
6	109	1.37	1.70	2	2.32	Slightly disturbed	0.46	Moderate
7	46	1.43	1.57	2	3.13	Slightly disturbed	0.40	Moderate
8	69	1.98	2.36	2	2.66	Slightly disturbed	0.52	Moderate
9	24	1.85	2.52	2	1.77	Slightly disturbed	0.55	Good

The MDS plot (Figure 6) revealed a clear separation of the stations according to the seasons. In the wet season, Stations 6, 7 and 8 were highly similar (ANOVA, $p < 0.01$) (Figure 6). Station 1 for the wet season as well as Stations 1, 3 and 4 for the dry show a relatively tight cluster as well. Station 9 appears to show some difference when compared to the other stations in the dry season.

The stress level of this plot, however, appears to be relatively high indicating there is weak 2-dimensional arrangement of points that reflect their similarities.

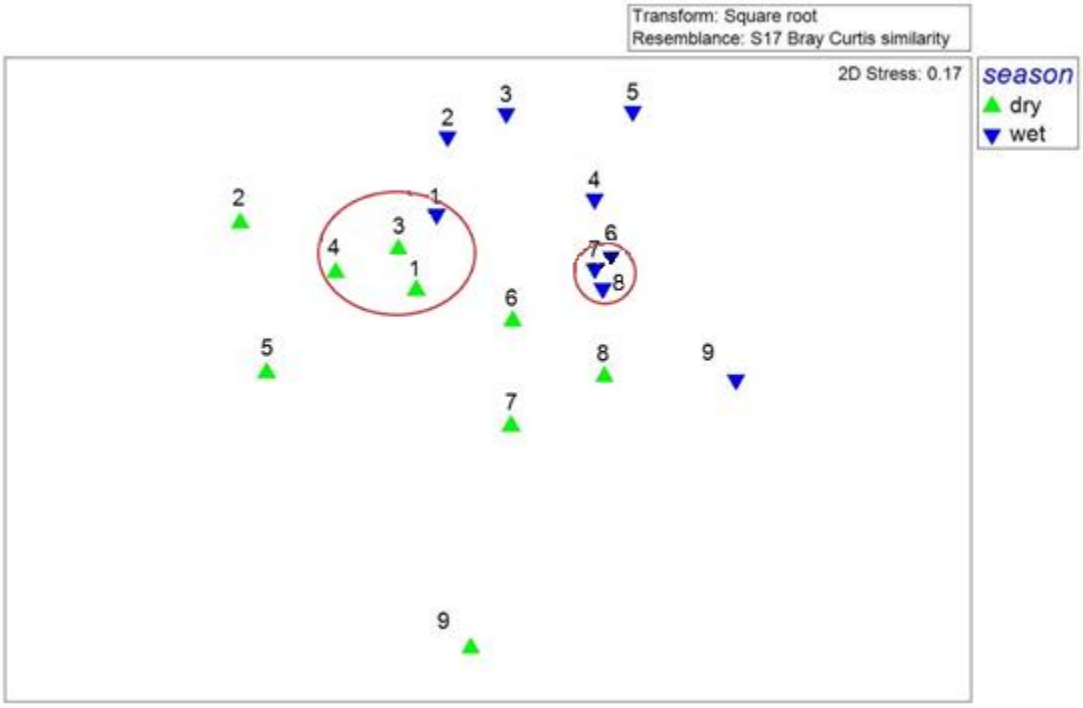

FIGURE 6: MDS PLOT FOR WET AND DRY SEASON STATIONS SAMPLED AT PORT GALEOTA

The dendrogram plot (Figure 7) shows similarities of greater than 50% between Stations 6 and 7 for the wet season as well as Stations 7 and 8 for the dry season.

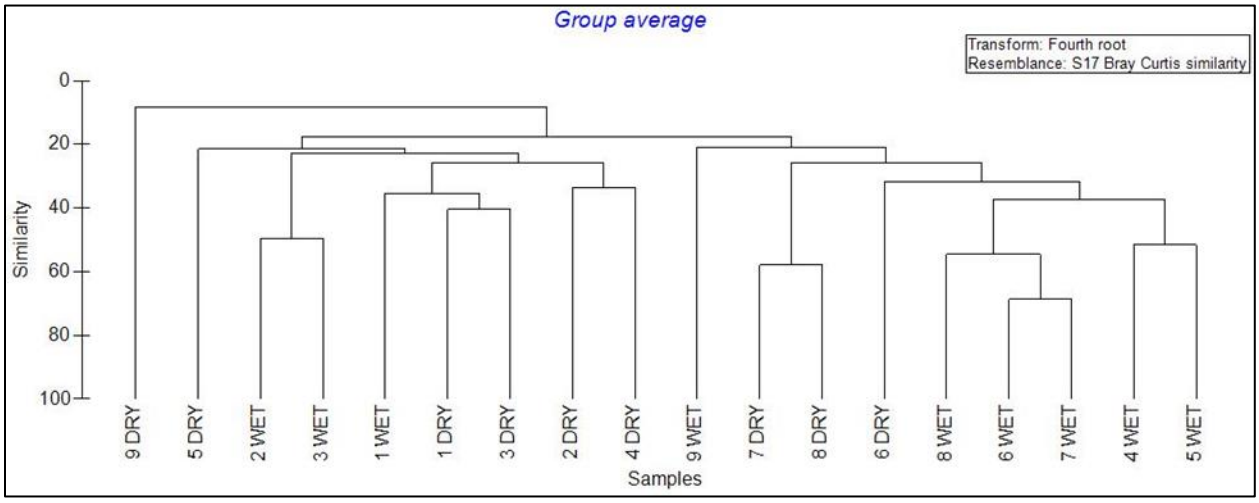

FIGURE 7: DENDROGRAM PLOT OF MACROFAUNAL DATA COLLECTED FOR WET AND DRY SEASONS

A similarity of percentages test (SIMPER) was carried out to determine which taxa were most responsible for the groupings seen for the both seasons. The results of these analyses indicated that for the dry season, the polychaete, G. maculata contributed to 14.92% similarity, followed by Leptochelia sp. with 12.25%, P. hawaiiensis with 10.33%, Ophiofragmus filograneus (Lyman, 1875) with 9.37% and Magelona sp. with 8.81%. The top ten taxa accounted for 76.94% of the observed grouping distinction.

For the wet season, *G. maculata* accounted for the highest percentage similarity once again with 23.58%, followed by *Siriella sp.*, 15.45%; *P. cirrifera*, 15.34%; *C. pygmaea*, 12.83% and *O. petiolita*, 5.50%. The top ten taxa accounted for 86.74% of the observed grouping distinction. SIMPER analysis showed an average similarity among the dry season samples of 19.86 and 31.05 for the wet season. An ANOSIM confirmed the hypothesis that there was *"no difference in taxa composition between the dry and the wet season"*. The global R value obtained was low, suggesting an even distribution between groups (R= 0.323), and the result statistically significant (p= 0.017, 999 permutations).

A second ANOSIM also confirmed the hypothesis that there was *"no difference in taxa composition among the stations sampled."* Like the first test, the global R value obtained was positive and low (R= 0.355), and the result statistically significant (p= 0.017, 999 permutations). ANOSIM therefore concluded there was no significant difference between the stations samples and the seasons sampled.

3.2 ENVIRONMENTAL DATA

Temperature and pH

For both seasons, temperature and pH remained constant for all stations, varying by 1.5^{o}C for the time period sampled (Table 4). Temperatures ranged from a minimum of 27.7^{o}C to a maximum of 29.2^{o}C (Table 4). pH remained constant throughout both seasons of sampling, ranging from 7.3 to 8.3 (Table 4). pH levels fell within the acceptable United State Environmental Protection Agency (1995) limit for aquatic life (6.0 to 9.0).

TABLE 4: PHYSICOCHEMICAL PARAMETERS FOR THE DRY AND WET SEASONS FOR PORT GALEOTA

	Dry Season								
Parameter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
pH	8	7.9	7.3	8.1	8	8.1	8.1	8.1	8.1
Salinity ‰	36.3	36.4	36.3	36	35.6	36.4	36.2	36.2	36.6
Temp ^{o}C	28	27.7	27.7	28.2	28.7	28	28.5	28.7	29.2
D.O. mg/l	6.3	6.6	6.6	6.6	8.1	5.9	6	6.2	6.3
	Wet Season								
pH	8.3	8.3	8.3	8.2	8.3	8.1	8	7.8	8.2
Salinity ‰	24.9	26.5	24.7	25.2	25.6	24.6	27.3	23.9	25.5
Temp ^{o}C	28.3	28.5	28.4	28.1	28.1	28.2	28.5	28	28.4
D.O. mg/l	7.2	7.3	7.3	6.8	6.5	6.6	6.1	6.4	6.9

Salinity

There was a marked decrease in salinity from the dry season to the wet season. The lowest salinity recorded in the dry season was 35.6‰ at Station 5 and the highest value recorded was 36.6‰ at Station 9 (Table 4). For the wet season, the highest salinity was recorded at Station 7 at 27.3‰ (Table 4). The lowest value was recorded at Station 8 at 23.9 ‰ (Table 4). Salinity showed no significant correlation with species abundance (ANOVA, $p>0.05$), however there were significant correlations with species diversity (ANOVA, $p<0.01$) and species richness (ANOVA, $p<0.01$).

Dissolved Oxygen (DO)

DO remained constant throughout both seasons. In the dry season, Station 6 recorded the lowest value of 5.9 mg/l, while the highest value of 8.1 mg/l was recorded at Station 5 (Table 5). In the wet season, values remained relatively constant ranging from 6.1 mg/l at Station 7 to 7.3 mg/l at Stations 2 and 3 (Table 5). USEPA (1995) states a dissolved oxygen level of 5.0 mg/l is adequate to sustain marine life, and all stations sampled were well above this limit. Dissolved oxygen showed positive correlation with species abundance, the higher the DO, the ANOVA ($p<0.05$), richness, ANOVA ($p<0.01$) and diversity, ANOVA ($p<0.01$).

3.3 WATER CHEMISTRY

Ammonium

The USEPA (1989) (Miller, 1989) limit for ammonium is pH and temperature dependent. Based on the pH and temperature (Table 4), the limit for this environment should be 0.50mgl^{-1}. This value was exceeded at all stations measured across both seasons (Table 5). Kendall's tau showed significant correlation for ammonium with species richness and diversity (Table 6).

TABLE 5: CHEMICAL PARAMETERS FOR THE WET AND DRY SEASONS

Parameter	Dry Season								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
NO3-N/µM	0.15	0.17	0.26	0.31	0.04	0.23	0.50	0*	0.30
NO2-N/µM	0.10	0.05	0.09	0.15	0.13	0.09	0.12	0*	0.12
NH3-N/ mgl^{-1}	0.63	0.62	0.56	0.75	0.54	0.62	1.87	0*	0.97
RPO4/ µM	0.03	0.03	0.05	0.06	0.05	0.07	0.29	0*	0.27
	Wet Season								
NO3-N/µM	0.85	0.57	0.37	1.88	0.80	0.38	2.06	6.61	2.90
NO2-N/µM	0.06	0.05	0.04	0.04	0.12	0.07	0.06	0.07	0.08
NH3-N/ mgl^{-1}	0.77	0.66	0.62	0.80	0.86	0.76	0.68	1.11	1.08
RPO4/µM	0.24	0.19	0.18	0.21	0.31	0.28	0.23	0.26	0.22

TABLE 6: CORRELATION FACTORS FOR METAL AND CHEMICAL PARAMETERS SAMPLED WITH ABUNDANCE, RICHNESS AND DIVERSITY FOR MACROBENTHOS. *CORRELATION SIGNIFICANT AT THE 0.05 LEVEL.

Parameter	abundance	richness	diversity
Copper (Cu)	0.11	0.11	-0.22
Nickel (Ni)	-0.08	0.08	-0.03
Chromium (Cr)	0.11	0.11	0.00
Lead (Pb)	-0.22	0.44	0.33
Iron (Fe)	0.06	0.611*	0.28
Cadmium (Cd)	N/A	N/A	N/A
Zinc (Zn)	0.06	0.28	0.06
Nitrate (NO_3)	-0.06	-.353*	-0.25
Nitrite (NO_2)	-0.08	0.01	-0.04
Phosphate (PO_4)	0.27	-.376*	-.362*
Ammonium (NH_4)	0.08	-.379*	-.394*

Nitrates and Nitrite

Nitrate levels ranged from 0.04µM at Station 5 to 0.5µM at Station 7 during the dry season (Table 5). For the wet season, levels ranged from 0.37µM at Station 3 to 6.6µM at Station 8 (Table 5). This showed a marked increase from the dry season to the wet season.

Nitrite levels for the dry season ranged from 0.05µM at Station 2 to 0.15µM at Station 4 (Table 5). The lowest value for the wet season was recorded at Station 4 with a value of 0.037µM and the highest value was recorded at Station 5 with a value of 0.12µM (Table 5).

Nitrite levels showed no correlations with abundance, richness and diversity (Table 6). Nitrate levels showed no correlation with abundance, but with richness and diversity (Table 6).

Phosphates

The USEPA does not give a value for phosphates in the marine environment, however other guidelines exist such as the Australian and New Zealand Guidelines for Fresh and Marine Water Quality, which lists an acceptable standard for marine phosphates as <0.05 mg/l (which is equal to 1.61µM) (ANZECC, 2000). None of the stations recorded exceeded these guidelines as the maximum phosphate level recorded for the dry season was at Station 7 at 0.29µM (Table 5).

Stations 1 and 2 recorded the lowest values with 0.03µM (Table 5). For the wet season, the maximum phosphate value was recorded at Station 6 at 0.28 µM (Table 5). Station 3 recorded the lowest value at 0.18 µM (Table 5).

Kendall's tau showed significant correlation between phosphate levels with richness and diversity (Table 6).

Heavy Metals in Sediment

All metals fell well below the USEPA (1995) limit for metals in saltwater (Table 7). There were no correlations between heavy metal concentration and abundance, richness or diversity of the benthic organisms except for Iron (Fe), which showed a significant positive correlation with species richness (Table 6).

TABLE 7: METAL VALUES AT THE STATIONS SAMPLED AND THE USEPA (1995) LIMITS FOR SALTWATER

Station	Cu µg/l	Ni µg/l	Cr µg/l	Pb µg/l	Cd µg/l	Zn µg/l	Fe µg/l
1	0.014	0.001	0.013	0.004	BDL	0.093	9.124
2	0.010	0.001	0.013	0.006	BDL	0.090	13.676
3	0.025	0.002	0.013	0.003	BDL	0.092	14.022
4	0.010	0.001	0.008	0.004	BDL	0.064	7.642
5	0.011	0.001	0.009	0.002	BDL	0.102	7.706
6	0.026	0.001	0.009	0.001	BDL	0.088	6.551
7	0.011	0.004	0.012	0.002	BDL	0.058	6.275
8	0.010	0.011	0.014	0.001	BDL	0.065	6.155
9	0.039	0.016	0.021	0.004	BDL	0.190	16.609
USEPA limit	*3.100*	*8.200*	*50.000*	*8.100*	*7.900*	*81.000*	*N/A*

Principal Component Analysis

Principal Component Analysis (PCA) is a multivariate technique used to summarise multiple variables and their relationships in two dimensional space. PCA analysis was conducted using PRIMER 6 software. The PCA analysis for Point Galeota (Figure 8) shows that the dry season stations were mostly influenced by salinity with the exception of Stations 9 and 7, which were mostly influenced by ammonium. The trends observed with the physicochemical parameters for the wet season stations appeared be mostly influenced by phosphate, temperature and pH.

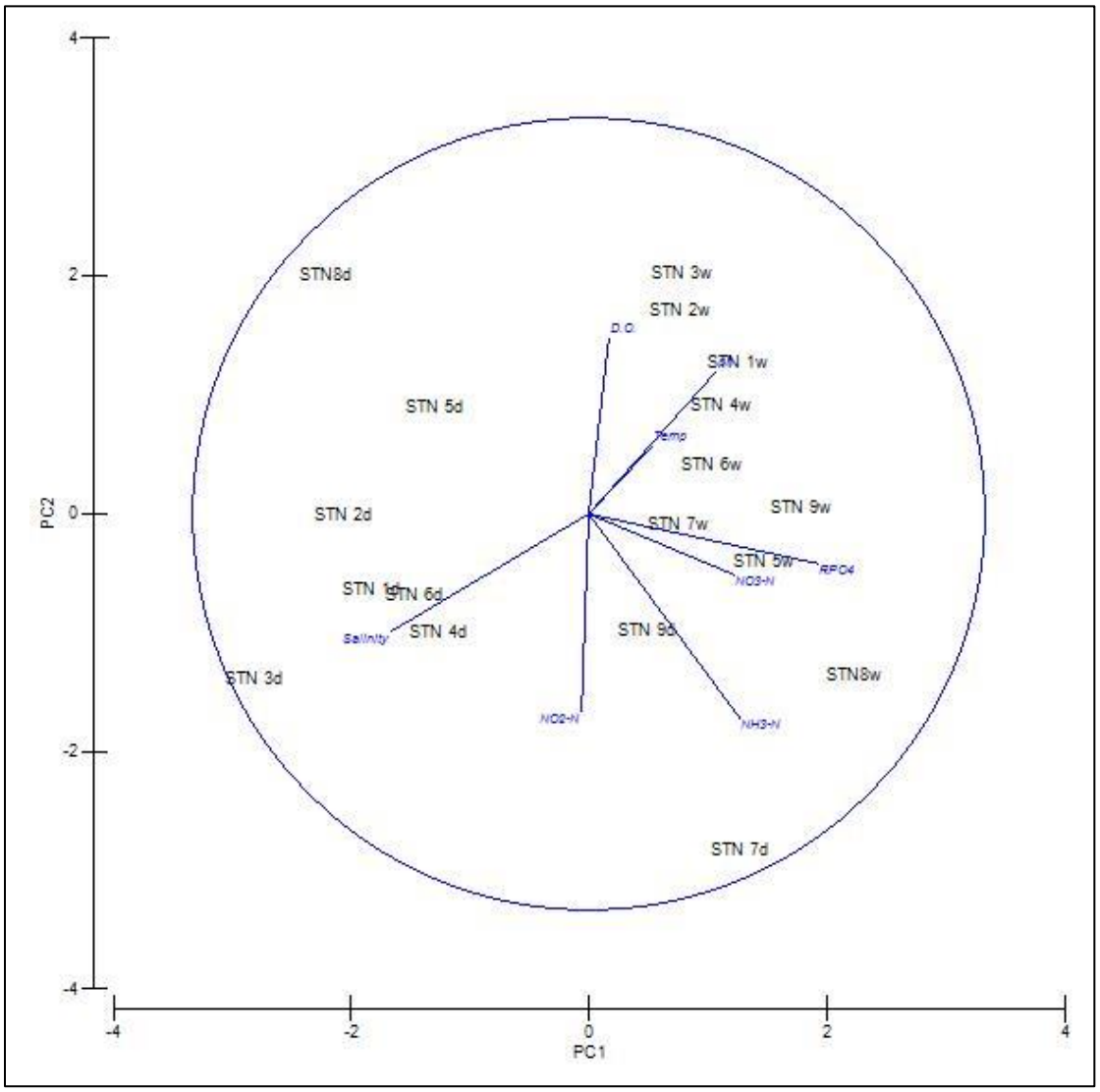

FIGURE 8: PRINCIPAL COMPONENT ANALYSIS FOR PHYSICAL AND CHEMICAL PARAMETERS WITH MACROBENTHIC COMMUNITIES

3.4 DISTURBANCE ANALYSIS

Several ecological indices were applied to assess sediment quality based on the response of the soft-bottom macrobenthic structure to changes in the environment. All stations showed generally high levels of abundance, diversity and richness. For the dry season, Stations 1, 2 and 3 which were located some distance away from the port appeared to have abundance, richness and diversity numbers that were similar to the stations located close to the berthing area (Stations 4-9).

4 DISCUSSION

All sampling stations whether close to the berthing area or outside of the berthing area showed relatively consistent levels of species diversity according to t-tests. There appears to be little anthropogenic stress from port activities. The benthic community does not appear to be stressed as most stations across both seasons show Shannon-Wiener Indices that would suggest moderate to slight pollution (Jhingran *et al*., 1989). This is also supported by the Disturbance Classification based on the AMBI Index which classifies the majority of stations as "Slightly Disturbed" with three stations being classified as "Undisturbed". The presence of sensitive species (Ecological Groups I and II) (Borja *et al*., 2012) in high abundances, supports the view that the Port at Galeota is minimally impacting the surrounding environment. Amphipod species are normally absent in areas of high levels of pollution (Pearson and Rosenberg, 1987), however amphipods accounted for 50% of the organisms recorded, thereby further supporting the idea that there is minimal impact from pollution at this port. Opportunistic species were only recorded in significant numbers at Station 7 for the wet season, which indicates some type of disturbance (Grassle and Grassle, 1974; Savidge and Taghon, 1988; Sukumaran *et al*., 2016) in this area. This was a marked change from the dry season where Station 7 was dominated by sensitive species. However, such a change may not have been as dramatic as suggested by the analysis as only 10 different species were recorded during the wet season as opposed to 12 during the dry season. Dissolved oxygen showed strong correlation to macrobenthic abundance, richness and diversity which could have contributed to the health of these benthic communities. The correlation analyses also indicated that salinity, ammonium and phosphates controlled the spatial distribution of benthic species.

Among the organisms recorded for the wet season, was the opportunistic bivalve belonging to the genus *Donax* which increased in number from the dry season to the wet season. The crustacean *C. pygmaea* which is normally an indicator of a well-flushed system (Oliver *et al.*, 2007) also decreased in number from the dry season to the wet season. The reduction in sensitive species and an increase in opportunistic species did not affect the disturbance classification of Station 7 from one season to another however, the Ecological Status was decreased from "Good" to "Moderate" based on M-AMBI values.

Spionid species are often noted as indicators of pollution (Pearson and Rosenberg, 1987; Hiscock, 2004; Dean, 2008). However, the ubiquity of the spionid, *P. cirrifera* throughout the stations sampled may not necessarily be an indicator of pollution as benthic communities will often respond in their own ways to different environmental stressors (Dean, 2008). As such, the classification of the environment as one that is slightly disturbed remains. Factors other than pollution appear to influence the macrobenthic environment such as salinity. The decrease in salinity from the dry season to the wet season showed that there is freshwater input to the area. Freshwater input then affected the composition of the macrobenthic community in terms of diversity and richness especially closer to the nearshore areas as they were very shallow. Physiological factors appear to be the major influencers of the macrobenthic community when compared to anthropogenic stressors.

Correlation analysis showed anthropogenic stress appeared to be minimal in the port area as no correlation was found between the heavy metals tested and the benthic community except for iron. This is as port activities usually exhibit significant stress on benthic communities usually leading to decreased numbers and inhibition of benthic community development (Rezayi *et al*., 2014). This does not appear to be the case at Port Galeota.

Benthic surveys conducted by Coastal Dynamics Limited in January 2011 of the Galeota License Block and extended area revealed lower numbers of macrobenthic organisms (Coastal Dynamics Limited, 2013). The Coastal Dynamics study reported a total of 573 specimens from 87 different taxa as compared to 1713 individuals from 109 different taxa in this study. Of the 573 specimens collected, approximately 58% were Annelids (polychaetes), 34% Arthropods (Crustaceans) and 4% Molluscs as compared to this study which found amphipods accounting for 50% of all species found with the second most abundant species being Annelida (23%) followed by Mollusca (4%). The difference in proportion of taxa observed can be attributed mainly to the high number of amphipods observed during the dry season, which accounted for a significant portion of the individual organisms recorded. Coastal Dynamics (2013) states that the percentage representation by each faunal group is typical for the soft bottom sediments along the south eastern coast of Trinidad (IMA 1996; EPAS 2004; Gobin 2006, 2008), with a similar prevalence of polychaetes being observed in 2011, (Mangal 2011).

The most abundant faunal species observed within the sample population of 2011 were *Ampelisca* sp a. and *Onuphis* sp.a. Other common species included *Maldane* sp. *a., Melinna maculata* (Webster, 1879) and Melitidae (lpil). The most abundant species observed in 2017 were *G. halophilus, G. maculata, P. cirrifera, Armandia sp 2., Prionospio sp.*, Nemertea, *O. petiolita, Leodamus sp., B. spinicarpus* and *C. pygmaea.* These organisms suggest a healthy and relatively undisturbed benthic environment in both instances. However, the differences in the number and composition of the populations observed from 2011 to 2017 can be due to the reasons stated below.

The difference in the number and type of organisms found appears to be two-fold. The Coastal Dynamics samples of 2011 were taken further offshore than those sampled in 2017. This can account for differences in the number of species observed. Also, three replicates were taken during the 2011 sampling event for one season compared to six replicates taken in 2017 across two seasons. Enough samples may not have been taken in 2011 to produce an adequate picture of the macrobenthic community off the south-eastern coast.

Another port study was conducted at the Port of Point Lisas in 2010 (Gobin, 2016). Thirteen stations were sampled in replicates of three. That study yielded 412 polychaete individuals belonging to 43 different species with the dominant polychaete being *Paraprionospio pinnata* (Ehlers, 1901) of the Spionidae family. This was a stark reduction from the same study conducted in 1985 (Gobin, 1988) where 3140 polychaete individuals were observed, belonging to 70 different species, however some of this difference can be attributed to more stations (25) being sampled in 1985. This Port of Galeota study appears to be consistent with the results found at Port of Point Lisas in 2010 as a similar number of polychaetes (562) were recorded albeit from slightly less species (36).

Another study conducted by Agard *et al*., (1993) indicated that benthic community species on the western coast of Trinidad stretching from Pointe-a-Pierre to La Brea were “grossly to moderately stressed”, in stark contrast to the communities observed in this study. However, these communities are subject to chronic and natural oil seepage from oil production activities on Trinidad’s south-western coast.

At this point, it is difficult to state definitively whether species identified at this port were invasive given the paucity of data with regard to benthic communities of Trinidad and Tobago. However, a number of species may have been potentially described for the first time in the waters of Trinidad, pending further investigation and confirmation: *Lumbrineries latreilli, Nothria conchylega, Euclymene sp, Leodamus sp., Notomastus latericeus, Ceratonereis sp 1, Glycera sp, Goniada japonica, Nereis lamellosa, Pisionidens sp, Prionospio cirrifera, Raricirrus sp., Bamarooka tropicalis, Grandidierela halophilus, Birubius spp, Cyproidea sp.,Parelasmopus spp., Shoemakerella barnardi, Chondrochelia dubia, Leptochelia sp., Cumella pygmaea, Cumella sp., Natica canrena, Renilla amesthystina.*

This report can serve as a baseline for future research on the Port of Galeota to compare the impact of increased anthropogenic activities, including introduction of invasive alien species, over time.

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