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USE OF THE WATER QUALITY INDEX AS INDICATOR OF TOURISM IMPACT MANAGEMENT IN PARATY, RIO DE JANEIRO/BRAZIL

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Highlights

- Tourism development on the south coast of Rio de Janeiro;
- Water quality impacts resulted from human presence;
- We selected 20 water sampling stations and evaluated the seasonal water quality variation;
- Water quality changes between seasons became clear;
- The Water Quality Index (WQI) was very useful for the classification of the waters monitored.

Purpose

- The main objective of the present paper is to detect the tourism influence in the water quality of the municipality of Paraty and surrounding water bodies, analyze individual parameters and use the WQI.

Design/methodology/approach

- In the present paper a simple management tool was applied in order to prevent future tourism impacts in coastal areas.

Findings

- Although considered in its natural state, the area already showed impact signals.

Research limitations/implications

- The analysis need to be more enhanced for finding the spatiotemporal evolution in the estuarine environment.

Practical implications

The paper provides a starting point for minimizing the negative impacts of tourism.

Originality/value

The present paper contributes so that tourism may become a positive factor of local development.

ABSTRACT

One of the most important indirect impacts of tourism in areas of poor sanitation is that of a worsening in local water quality. In this context, environmental monitoring is fundamental for the control and support to environmental management activities. However, the study of unpolluted or slightly modified areas is essential in order to prevent impacts and for the implementation of solutions for the coastal management. The area investigated in the present study is a potentially unpolluted Atlantic forest ecosystem in the south of Rio de Janeiro state, Brazil. Two seasonal river and sea water sampling campaigns undertaken at twenty sites were performed to characterize physical-chemical parameters, inorganic nutrient,

fecal and thermo tolerant coliform bacteria and PAH. The results from this study indicate that the water quality in this area is already affected by tourism activity on Cairuçu Environmental Protection Area. It was found that the WQI was very useful for the classification of the waters monitored.

Keywords: *Domestic waste; Water Quality Index; Tourism Impact; Hydrocarbon*

1. INTRODUCTION

Tourism industry is currently among the world's largest activity and fastest growing economic sector, representing 5% of global economy (Buckley, 2011). In this scenery, coastal tourism is a significant portion of the tourism sector that is expected to be quickly developed in terms of both its volume and value (Vogt, 1997), resulting in ongoing concerns about its environmental sustainability (Bulleri *et* Chapman, 2010). The resulting demographic fluctuation can directly impact the ecosystems through localized or diffused pollution. The pollution of water bodies has turned into a main environmental problem nowadays, affecting human health, water resources, and ecosystems (Tarazona, 2014).

Distinct areas in the Earth are facing different types of problems linked with the occurrence, use and control of water, which may impact negatively the sustainability of these resources. Water contamination in tourist areas can be resulted by insufficient or non-existent waste water treatment. In many cases, hotels and other recreation facilities do not have their own sewage treatment plants and are not connected to any system (Kocasoy *et al.*, 2008). On the other hand, the increase of waste load during the tourist period cannot be absorbed by the public treatment net because of local limited infrastructure.

Nowadays, many physical and chemical parameters used characterize water quality and water contamination (Taner *et al.*, 2011). Conventional methods used to analyze and carry water quality are usually based on the comparison of the pattern values with the local regulations (Liu, et al. 2012). However, it is impossible to plainly characterize water quality, taking into consideration the behavior of every individual parameter separately (Ministerio de Obras Públicas y Urbanismo, 1983). The solution is the integration of the values of a group of physical and chemical variables into a unique classification. So, the concept of Water Quality Index (WQI) has been developed by the National Sanitation Foundation (NSF) in 1970 (Brown et al, 1970) as a simple and effective evaluating composite water pollution tool (Banerjee and Srivastava, 2009).

WQI results in a single number, like a class, that shows overall water conditions at a certain area and time based on several water quality factors (Bordalo *et al.* 2007). WQI is a dimensionless number that connects multiple water quality parameters into a single grade by normalizing values to subjective classification curves (Sharifi, 1990).

The main objective of the present paper is to detect the tourism influence in the water quality of the municipality of Paraty and surrounding water bodies, analyze individual parameters and use the Water Quality Index during the high and low touristic season.

2. STUDY AREA

Located in the south coast of the State of Rio de Janeiro, Brazil, Paraty represents a Municipality of 30.000 inhabitants (Conti and Irving, 2014), of which approximately 15.000 are concentrated in the urban area, in and near the City of Paraty (Figure 1). The other 15.000 are dispersed in smaller countrified communities around the Municipality. Most of these individuals work with tourism and fishing. Paraty (RJ) is recognized as one of the biggest tourist attractiveness among the municipalities of the state of Rio de Janeiro and also comprises 40% of the Bocaina Mountains National Park (Conti *et* Irving, 2014).

The study area lies in a legal conservation area, called Cairuçu Park. It is surrounded by the Atlantic Rainforest, presenting natural touristic spots such as waterfalls, rivers of crystalline waters, mangroves and beaches in natural status, and it is an important protected area for the conservation of the Atlantic Forest biome (Conti and Irving, 2014). Currently, this region is passing through a developing tourism process, and it is the second village in terms of numbers of habitational units, which corresponds to approximately 900 beds, representing 14,19% of the total in the area of Paraty (Prefeitura Municipal de Paraty, 2003). In the summer months (high season) it receives as many as 40.000 visitors, in a single weekend (Conti and Irving, 2014), increasing volumes of sewage, garbage, boats and cars in adjacent areas, potentially resulting in environmental impacts (Conti and Irving, 2014).
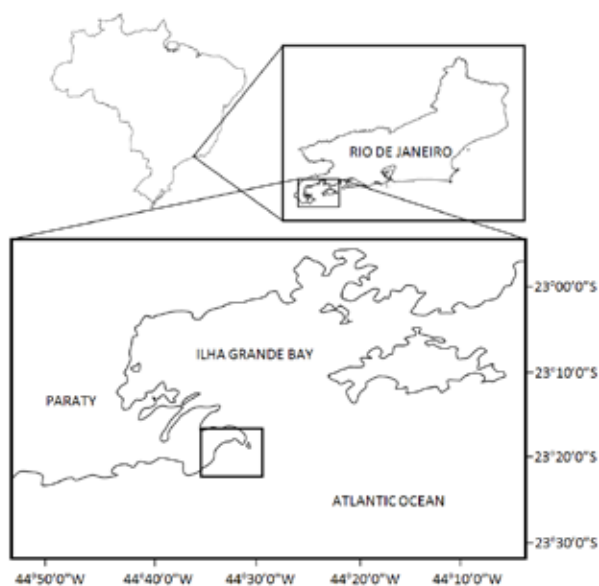
Figure 1. Study Site

3. MATERIALS AND METHODS

According to the approach applied, 20 sampling sites (7 marine water stations – "M" and 13 fluvial water stations – "R") have been selected as representative of the estuarine system waters (Figure 2) during the ebb tide, in both campaigns (winter and summer seasons – called in the present study as "low" and "high" season respectively). Samples were collected with Van Dorn bottles at subsurface depth and stored in sterilized glass bottles. Adequate methods were taken for quality assurance of the collected water samples.

Measurements of water temperature, turbidity, conductivity and pH were taken "*in situ*" using a Hanna HI98129 probe. Dissolved oxygen concentrations (mg/L) and saturation

(%) within the water column was measured using a Jenway 970 Portable DO2 Meter.

Laboratory analyses were carried out for the determination of total nitrate, total phosphate, biochemical oxygen demand (BOD$_5$), solid particular matter (SPM) and fecal and total coliform counts. Nitrates were analyzed using a cadmium reduction method. Phosphates are tested using potassium persulfate followed by sulfuric acid digestion. Values of BOD were determined by the differences between the initial measurement of dissolved oxygen concentration (mg/L) and the resulting concentration of dissolved oxygen after the 5 day period (EPA, 1999). Fecal and thermo tolerant coliform were analyzed using method 1680 (EPA, 2002).

Sixteen PAHs compounds were identified by the US Environmental Protection Agency (EPA) as priority contaminants (Guo et al, 2007) and they have their main significant impacts on marine environments, since they include the largest known class of chemical carcinogens and mutagens (Cardellicchio *et al*., 2007). The determination of Poliaromatic Hydrocarbons in water was done through the chromatographic method according to EPA Method 8272.

For the determination of the water quality index of the different fluvial sampling stations studied, nine parameters were used to apply NSF-WQI: dissolved oxygen, thermotolerant coliform, pH, temperature, total phosphate, nitrate, turbidity (NTU), biochemical oxygen demand and total suspended solids (Brown et al, 1970).WQI was computed for each factor as the product of Q-value and weighting factor.

WQI = Q-value x Weighting factor

The overall WQI is the weighted average of all Q-values:

Overall *WQI = Σ(Q-value x Weighting factor) / ΣWeighting factors*

Figure 2. Sampling Stations

Table 1 shows the values suggested by the classifications resulted from the calculation of WQI, according to European Standards (EU, 1975). When the values of WQI are in the range of 0–19, the water is assorted as ''very bad''; between the values of 20-36 the water is considered as ''bad''; in the range of 37-51 the water is classified as ''medium''; lastly, when the WQI values reach values between 52-79 and 80-100 the water is classified as ''good'' and as ''excellent'', respectively (Jonnalagadda *et* Mhere, 2001).

Table 1. Water Quality Index (WQI) classifications

Index (WQI)	Water Classification
80 – 100	excellent
52 – 79	good
37 – 51	medium
20 – 36	bad
0 - 19	very bad

Source: U.S. EPA. (1978)

4. RESULTS

The goals of water quality surveys are to describe spatial and temporal fluctuations in water quality and identify the variables that influence the patterns (Mueller et al., 1997). Similarly to other parameters used as indicators of water quality in an aqueous environment evaluation, the pH is important for coastal waters studies and physics-biology couplings (Frankignoulle *et* Borges, 2001). No further, aquatic organisms that permanently live in the water are particularly sensitive to changes in pH (Mudge *et* Haller, 2009). Decreasing values of pH into acidic conditions can also influence the mobility of other pollutants including heavy metals (Violante *et al*., 2010). Finally, according to Grupta *et al.,* 2011, pH seems to be influenced by the increasing use of alkaline detergents discharged in domestic sewage.

In the present study, in the high season, pH values varied between 5,95 a 7,99. On the other hand, in the low season variation ranged between 6,25 e 8,38 in the same sites. No anomalous variation where recorded in the present survey. In general the pH was within the limits of the standard values (APHA, AWWA, WEF, 1999). For potable water, a pH range between 6.0 and 8.5 is recommended (U.S. EPA, 1978). In both campaigns the fluvial sampling stations presented lower values. Comparing both sampling site groups (fluvial and marine) differences became clear. Resulted from the high concentrations of ions in high-salinity waters, seawater provides substantial buffering capacity against pH shifts (Ringwood and Keppler, 2002). So, while the pH of open-ocean seawater typically ranges between 7.8 to 8.4, estuarine pHs can be significantly lower, experiencing stressful changes to their inhabitants (Fabry *et al*. 2008).

The difference between the average values of both seasons can be attributed to the meteorological regime and its influence in the photo synthesis. In the present study the pH values did not suggest any anomalous result. On the other hand, while the actual magnitude of the differentiation may seem small, it is important to consider that pH is based on a log scale; therefore, even a change of 0.2 to 0.5 units can have enormous physiological impacts.

The estuarine water salinity can indicate the amount of freshwater mixed with seawater in a certain area. The tidal regime also contributes to the salinity balance together with wind and currents dynamic. Additionally, human activity can affect salinity. If water is taken from a river for human use, as in the example of crop irrigation, there will be less freshwater flowing downstream and an estuary will become more saline. In the present study salinity varied between 0,01 to 33,03. The differences between fluvial and marine patterns are clear in the present study (Figure 3).

The water temperature is a factor that can vary considerably over time and between places. The dissolved oxygen concentration in the water is directly affected by temperature, and therefore it is important to understand the variances of temperature in the water bodies. In estuarine water bodies, temperature can be influenced by discharges of water from municipal effluent, which are potential sources of thermal pollution in the coastal zone. In the present work there were no impact signals. The temperatures varied between 21,27 and 27°C (Figure 3) in the high season. On the other hand, in the low season values ranged between 18,11 and 25,6°C. Temperature variations showed to be aleatory between both campaigns and the discontinuous monitoring does not permit the understanding of the daily variation of this parameter.

Dissolved oxygen (DO) is frequently used as an indicator of water quality and is considered by EPA as an additional primary response parameter in environments that are passing through hypoxia (U.S. EPA 2001). This factor is strongly impacted by a combination of physical, chemical, and biological variables as well as charges of oxygen demanding substances (Mullholand et al., 2005; Quinn et al., 2005). The determination of dissolved oxygen concentration is significant to calculate the natural situation of the water and to register environmental impact signals such as eutrophication or organic pollution (Carmouze, 1994).

The marine waters all over the sampling sites were very well oxygenated in both campaigns. On the other hand, during the high season in the riverine sampling sites, oxygen concentrations varied between 2,64 and 12,75mg/L, suggesting anomalous patterns in stations 15R and 16R, corresponding to the Trindade village stations (Figure 3), where the lower values were registered. In the low season, values ranged
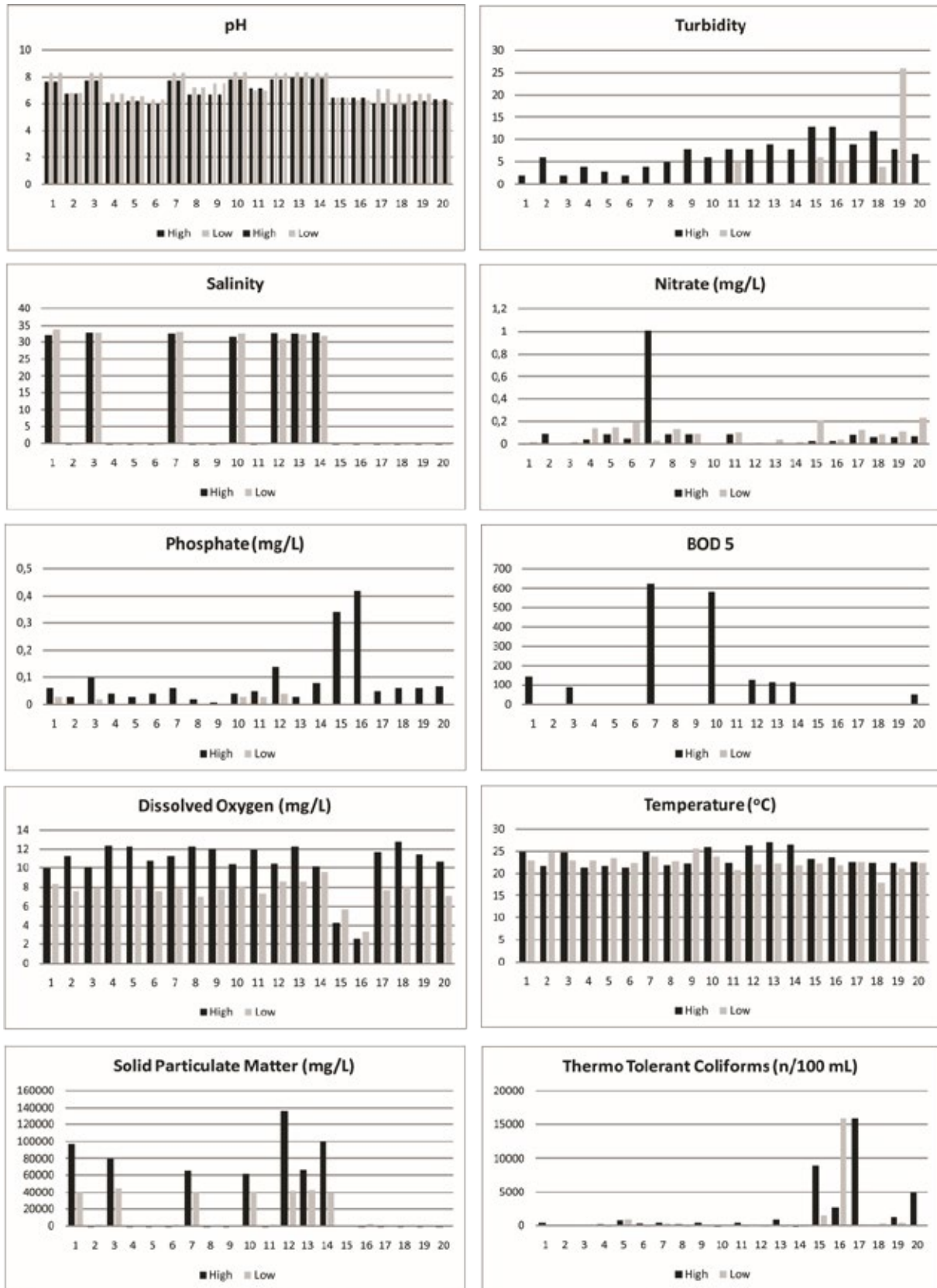
Figure 3. Results

between 3,4 e 9,6mg/L, repeating patterns of semi anoxic conditions in sampling sites 15R and 16R. The NEEA and NCCR studies used the limits of 2 and 5 mg L^{-1} to define the "fair/poor" and "good/fair" boundaries. However, Sheldon and Alber (2010) described some inconsistencies in the literature over the units used to describe oxygen concentrations: the often-incorrectly cited criterion for hypoxia of 2 mL O_2L^{-1} (Diaz and Rosenberg 1995) is equivalent to approximately 2.85 mg O_2L^{-1}.

High BOD indicates that there will be low concentrations of dissolved oxygen available for aquatic life and also the potential existence of bacterial contamination sources. In the present study, the BOD ranged between N.D. to 628 mg/L during the high season. In the low season, BOD showed values under detection limits.

Nutrients monitoring, particularly nitrogen and phosphorus, is essential since their availability influence the primary productivity in freshwater-aquatic environments. High levels of nitrate or phosphate can adversely impact surface-water quality through eutrophication or toxicity to aquatic life (Sheldon et Alber, 2011). According to Hermes and Silva (2004), phosphate concentration levels of 0,01mg/L are enough to maintain phytoplankton biomass, and concentrations of 0,03 to 0,1 mg/L (or higher) are propitious to result in an uncontrolled productivity. In the present study, the phosphate concentrations varied between 0,06 and 0,42mg/L in the high season. The values recorded in fluvial stations 3R and 12R, and marine stations, 15R and 16R, showed levels above the limit levels established by the Brazilian legislation (Ministério do Meio Ambiente, 2005), which establish the value of 0,025mg/L for fresh water, and 0,031mg/L for salt water (Figure 3). In the low tourism season, the values of the recorded levels varied between n.d. e 0,04. The higher values were recorded in sampling stations 15R and 16R, suggesting the possibility of anthropogenic influence according to other parameters analyzed in this study.

Nitrogen can be released to the environment by natural sources such as soil erosion or vegetal or animal detritus decomposition. On the other hand, anthropogenic sources can include soil fertilizers or animal/vegetal residues. According to the Brazilian legislation (Ministério do Meio Ambiente, 2005) the maximum accepted level is 0,7mg/L N, for fresh water. All the values of Nitrate concentrations were recorded below the limit concentrations established by the legislation (Figure 3) in both campaigns.

Suspended solids in the water column usually enter the aqueous system as a result of soil erosion from disturbed land or can be used as a tracer of the inflow of effluent from sewage plants. Suspended solid particles also occur naturally in the water from bank and channel erosion; ho-

wever, this process has been accelerated by human use of waterways. The present study showed clear differences between marine and fluvial sampling stations. In the fluvial stations values varied between N.D. and 91mg/L in the high season. On the other hand, the marine values varied between 62266 and 136526mg/L (Figure 3). Conversely, in the low season, concentrations were lower than the peak season. Estuaries are generally more turbid than marine and fluvial waters due to the input of sediment from rivers, the presence of dense populations of phytoplankton, and the strength of tidal currents that prevent fine particles from settling. There may be marked seasonal influences on turbidity in estuaries caused by changes in river flow. Floods generally increase turbidity levels.

Turbidity is influenced by the sum of many factors such as river influx, physical forces (tidal range, wind strength and direction), local geomorphology and sediment availability through a set of complex interactions involving turbulence dynamics, flocculation processes, solute transport, and sedimentation/erosion balance (Mitchell et al., 1998). Normally the highest turbidity conditions occur in the intersection freshwater/seawater. This is due to the movement of water in and out of the estuary by tides, causing fine particles to mix and be stirred up. In the present study the turbidity values varied between 2 and 13 UNT, and they were below the stipulated legislation in both cases, in fresh and salt water (Figure 3). The unique station that showed an anomalous result was station 19R, with a value of 26 UNT, which can be linked to the resuspension of bottom sediment during the sampling campaign. The studied ecosystem consists of a coastal line where many small river mouths are located. Thus, the low freshwater influx does not offer significant physical disturbance to the coast line. However, the riverbeds are predominantly composed of coarse grain size, not representing a source of fine material to the water column. On the other hand, turbidity dynamics is affected by salinity, since the presence of salt in estuaries has the effect of lowering turbidity. Finally, the low discharge of fresh water in the salty marine water tends to result in low turbidity as registered in the present study.

Freshwater compartments are likely to fecal contamination sources that are transported from the local watershed, including those from agricultural runoff and sewage, as well as from wild and domestic animals (Howell et al., 1995; Alderisio et DeLuca, 1999; Gerba, 2000; Guber et al., 2006). In the present study, the higher concentration was recorded in sampling stations 15R, 16R, 17R, 19R and 20R, suggesting the Trindade and Laranjeiras village streams as impacted riverine water bodies. The same pattern was recorded in low season and it was lower than the level recorded in high season. Differences between both campaigns suggest the increase of coliforms content in

the high season, supporting the possibility of overloading of the municipality infrastructure during holiday time.

Finally, in the present study, the PAH's concentrations were low in all samples sites. Aqueous PAH's were not detected during low boating activity. On the other hand, naphthalene concentrations were recorded in all the marine samples (range between 0,11 and 0,41ug/L) during the holiday time, suggesting the influence of the touristic vessels in the coastal water.

The WQI results recorded in the present study described an already impacted environment. Despite the fact that the vast majority of points are above the acceptable level, it is expected that an area located within the protected areas are classified as good or excellent quality. In spite of this, in the present study, only seven of the sampling stations (2, 4, 6, 8, 9 and 18) were classified as good, in the high season (Table 2). On the other hand, in the low season, almost all the samples showed improvement in the water quality, suggesting the influence of the increase of local population in the water quality.

The worst WQI results were recorded in the sampling sites 15R and 16R. Initially, the same stations where pointed by the individual parameters as critic stations, maybe because of the proximity of population concentration of Trindade and Laranjeiras villages.

Comparing the results of both campaigns it was observed a clear tendency in terms of the worsening of environmental condition in the high tourism season (Figure 4), suggesting that the local buffering capacity was transposed.

Table 2 WQI results and seasonal comparison

Season Sampling station	High	Low
2R	61.67	69.71
4R	53.46	65.53
5R	50.05	53.23
6R	56.73	63.80
8R	55.47	63.80
9R	52.79	62.64
11R	54.88	65.85
15R	42.68	48.22
16R	40.33	37.65
17R	44.19	58.36
18R	52.96	56.54
19R	50.86	56.85
20R	34.61	56.76

5. CONCLUSION

The present study involving seasonal monitoring does suggest polluting influence of tourism-related activities on these water bodies in the Cairuçu Environmental Protection Area. Eutrophication signals were registered, mainly in the Trindade community water bodies. The analysis need to be more enhanced for finding the spatiotemporal evolution in the estuarine environment. Other parameters need to be evaluated under more intense time series observation for the sustainable ecosystem management.
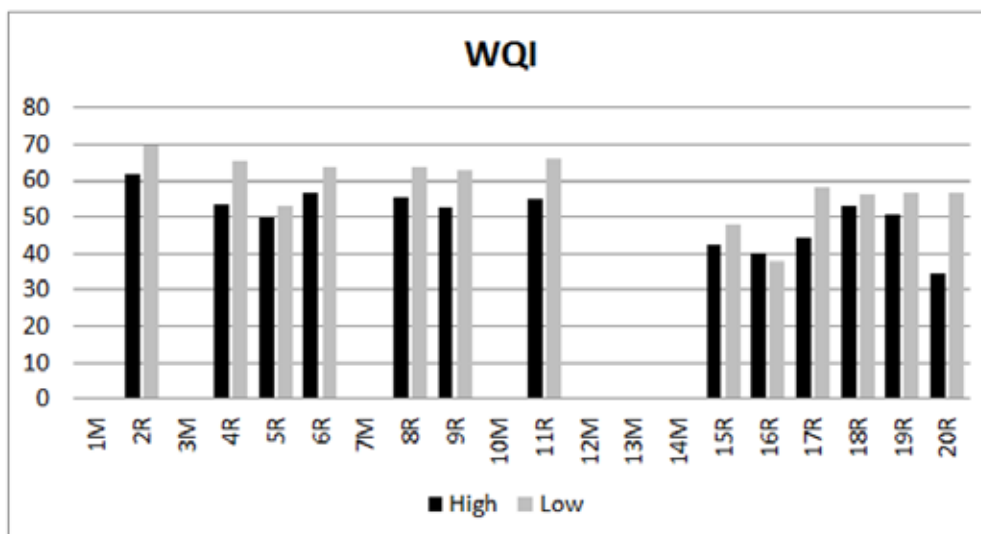

Figure 4. WQI comparisons

Once the sewage contaminated input alter the ecology of the coastal environment, greatly affecting the overall biotic community of the ecosystem, the information from the present study can be used for the future management of marine tourism in the Trindade village.

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