















Physicochemical, Coliform and Agrochemical Analysis to Evaluate the Water Quality of Coastal Freshwater Wetlands in Tonosí in Panama

Benjamin Braghtley¹ , Andres Fraiz-Toma^{2*} , Paola Gastezzi-Arias³ , Mileika Gonzalez² ,
Yessenia Gonzalez¹ , Antonio Clemente² , Alex Espinosa² , Edgar Arauz⁴ , Brillit Della Sera⁴ ,
Karen Dominguez⁵ , Quiariatjaryn Ortega-Samaniego⁵ , Almilcar Beitia⁴ 

¹ Faculty of Marine Science, Universidad Marítima Internacional de Panama, Ancón 07098, Panama

² Department of Deltas and Coasts, Wetlands International Latinoamérica y el Caribe, Ancón 0819 03717, Panamá

³ Wildlife and Health Laboratory, Universidad Estatal a Distancia, Sabanilla 474 2050, Costa Rica

⁴ Faculty of Agronomy, Universidad de Panamá, Panamá 3366, Panamá

⁵ Ministerio del Ambiente de Panamá, Ancón 0843 Balboa, Panamá

Corresponding Author Email: andres.fraiz@wetlands.org

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ABSTRACT

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Wetlands are sites of great ecological and economic importance. However, in Panama, studies that focus on evaluating the health of these ecosystems that constantly face anthropogenic effects are not common. In this work, an analysis of the water quality of farms located in what were coastal wetlands has been carried out, to measure the level of impact and change produced by the anthropological activities carried out and to be carried out in the area of study, located on the coast of Tonosí, Los Santos. For this, the NSF quality index methodology has been used, using variables obtained from 7 sampling plots each with varying numbers of subplots. Within these influences, a variety of emerging contaminants were observed, the greatest variety of these found in plot 2 in particular. The results point to undeniable contamination of the site based on agricultural and livestock activities as the main culprits.

1. INTRODUCTION

1.1 Wetlands and their importance

Wetlands are transition zones between terrestrial and aquatic ecosystems, these are characterized by having little depth [1, 2]. These ecosystems are characterized by being complex due to their dynamics in their physicochemical and biological components with high spatiotemporal variability [3, 4]. Isolated wetlands exist, whose moisture comes from groundwater, but these are rare. Wetlands have ecosystem importance and host great biodiversity. However, its greatest contribution - from a certain point of view - is its carbon reserve capacity [5-7]. Currently, the preservation and restoration of wetlands is one of the most effective alternatives to mitigate climate change, the loss of nurseries for commercial species, the loss of a hydrological buffer, and the acidification of both the oceans and rainfall [4, 8, 9].

In Panama, research on freshwater wetlands is scarce, so the conditions and environmental characteristics of these ecosystems are unknown. The expansion of the agricultural, livestock and urban frontier is modifying the ecological dynamics of wetland areas and their surroundings, causing progressive deterioration and loss of the biodiversity that inhabits them [10] so this Research provides basic information on the ecological status of these wetlands.

1.2 Water quality

Although a great deal of index methods has been used daily, there is not a single method recognized as the best [11]. The classification of water quality is very relative depending on the proposed use of this resource, location and type of resource (salt or fresh water) [12-17]. The quality of water depends largely on factors such as geology, geomorphology, location, as well as the intended use of said water source [12, 17-19]. This water quality can be perceived as being affected directly, indirectly by human actions or interventions [14, 18, 20]. According to Intergovernmental Panel on Climate Change (IPCC), climate change will affect the resource, so it is necessary to carry out constant monitoring to know both the quality and the availability of the resource in the water basins [21, 22].

The National Sanitation Foundation (NSF) water quality index is used in the Central American region, due to its wide range of variables and its flexibility with them [8, 21, 23, 24]. Among some of the investigations using the WQI NSF are: monitoring of water for consumption, monitoring of protected areas, characterization of water quality in recreation areas, among others [8, 24]. For the use of this water quality index, multiple variables are measured (percentage of dissolved O₂, fecal coliforms, pH, nitrate, phosphate, temperature variability, turbidity, total solids) [18-20, 25].

In the country, freshwater monitoring is very important due

to its use for human consumption and for the Panama Canal, however studies on coastal wetlands and analysis of water quality are scarce [26].

1.3 Project objective

The purpose of this study is to create a baseline that serves as a reference to identify anthropological interventions coming from productive activities such as agriculture and livestock in the coastal wetlands that are located on the transition line between mangroves and dry land, specifically close to the mouth of the Tonosí River, in the Tonosí Region, Los Santos Province in the Panamanian Pacific.

2. METHODOLOGY

2.1 Location of the study area

According to the study [27], different sampling areas were selected in Tonosí.

Tonosí is located southwest of the Azuero peninsula, in the province of Los Santos, Republic of Panama (Figure 1). The main economic and cultural activities in the region are agricultural, aquaculture and livestock. There are multiple livestock farms that were freshwater wetland areas and that were transformed for agriculture, livestock, among others.



Figure 1. Location of the study area, with sampling points
Source: Wetlands International

2.2 Measuring stations, physical-chemical variables and laboratory analysis

The sampling station were located in the lower basin of the Tonosí River. The samples were taken in February 2023, to perform analyses to measure the following parameters: nitrates, phosphates, fecal coliforms, emerging contaminants (agrochemicals) and physicochemical parameters such as dissolved oxygen, pH, temperature, conductivity and turbidity [26].

The physical-chemical parameters were analyzed in situ with the following equipment: multiparameter probe (OHAUS Waterproof pen meter) to measure pH, suspended solids, water temperature and conductivity, Refractometer (Hanna instruments) to measure salinity, turbidity meter (DELTA OHM), oxygen meter (Milwaukee MW605 MAX) to obtain the percentage of oxygen and dissolved oxygen. For these data collections, three replicates were carried out. The methodology described by methods generated by the Blue Carbon initiative [28] and adapted by the Ministry of the Environment of Panama and UNDP [27] was used, where

plots (TON) of size up to 125 meters long by 40 meters wide are worked (Figure 2), with subplots (sup), every 25 meters with a radius seven meters each. The maximum number of subplots was six, however, this varied depending on site conditions (Table 1). Once the subplots within them had been measured, water samples were taken. Surface and interstitial water samples were measured in situ with the aforementioned instruments. To take samples of the interstitial waters, a pipette was used and introduced up to 30 cm deep. As a clarification, surface water is considered to be the mass found above the ground that on average was not greater than 10 centimeters, and interstitial water is considered to be that found within the ground up to 30 centimeters deep.

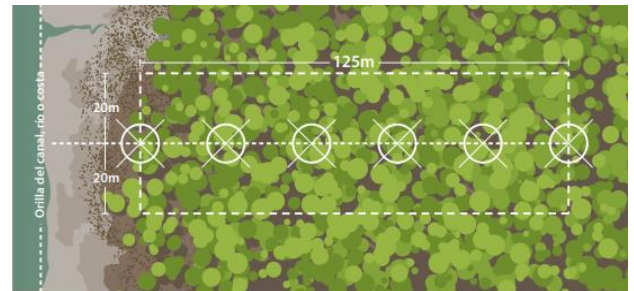


Figure 2. Design of sampling plots [26]

Table 1. Geographic coordinates of the areas of the sample plots in the coastal wetlands of Tonosí

Locations	Spot	Geographic Coordinates Datum WGS84	
		Latitude	Longitude
1. Cañas	C1-1	7.433117	-80.2321
	C1-2	7.4313	-80.2321
2. Cañas	C2-1	7.432574	-80.2336
	C2-2	7.432612	-80.2336
3. Bucaro	B1-1	7.353275	-80.3735
	B1-2	7.353126	-80.3736
	B1-3	7.352971	-80.3737
	B1-4	7.352838	-80.3738
	B1-5	7.352979	-80.3737
4. Bucaro	B2-1	7.353935	-80.3753
	B2-2	7.353925	-80.3755
	B2-3	7.353787	-80.3758
	B2-4	7.353796	-80.376
	B3-1	7.3557	-80.3799
5. Bucaro	B3-2	7.355581	-80.3798
	B3-3	7.355456	-80.3797
	B3-4	7.355346	-80.3795
	B3-5	7.355244	-80.3794
	B4-1	7.356927	-80.3861
6. Bucaro	B4-2	7.356751	-80.3861
	B4-3	7.356568	-80.3861
	B4-4	7.356402	-80.3861
	B5-1	7.355195	-80.388
7. Bucaro	B5-2	7.35502	-80.3881
	B5-3	7.354846	-80.3882
	B5-4	7.354711	-80.3882

To collect nutrient and coliform samples, amber bottles containing specific reagents for each analysis were utilized. These samples were stored in a cooler maintained at temperatures below 10°C and transported to the laboratory for processing. For contaminant analysis, specifically agrochemicals, the samples were analyzed at the Laboratory for Analysis of Pesticide Residues in Plants and Plant Products, a national reference government laboratory under

the Ministry of Agriculture. Two main analytical techniques were employed: gas chromatography with a triple quadruple mass detector (GC-MSMS) and liquid chromatography with a triple quadruple mass detector (LC-MSMS).

The first method, GC-MSMS, was applied to detect the following agrochemicals: acetochlor, alachlor, aldrin, BHC-Gamma, bifenthrin, cadusafos, clomazone, chlorpyrifos, DDD, DDE, diazinon, alpha-endosulfan, etofenprox, ethoprosfos, fenpropidin, hexachlorobenzene, metolachlor, mirex, molinate, pirimicarb, primiphos methyl, propiconazole, tefluthrin, terbufos, terbutylazine, tolclofos methyl, trifluralin, and vinclozolin. The second method, LC-MSMS, targeted the analysis of ametrine, atrazine, azoxystrobin, carbendazim, fenamiphos, fenamiphos sulfone, fenpropimorph, imazalil, imidacloprid, metalaxyl, monocrotophos, propamocarb, propoxur, and triadimefon.

The Environmental and Occupational Hygiene Laboratory, accredited by Panama's National Accreditation Council (CNA), was tasked with analyzing total coliforms and nutrients. For total coliforms, the SM 9223 B measurement technique was used, while phosphate levels were analyzed using the SM 4500 PE/HACH 10210 technique, and nitrates were assessed with HACH 10206. All samples were preserved in amber bottles within a cooler, kept at temperatures below 10 degrees Celsius, with a maximum of eight hours allowed between collection and delivery to the laboratories. Three replicates were conducted for all samples.

2.3 Estimation of indices

The water quality index (WQI) selected for the said analyzes is the NSF (National Sanitation Foundation), using the formula:

$$WQI = \sum_{i=1}^n Q_i W_i \quad (1)$$

In Eq. (1), i represents the multiple variables employed in this WQI, as detailed in Figure 2. The term Q_i denotes the subindex for each variable i , which is determined using standard values from subindex calculation tables. The W_i refers to the weighted value assigned to each variable, specified in Table 2 [8, 12].

Table 2. Weighted felling weights (W_i): Custom fabrication

Variables	% Weighted Weight
O ₂	0.17
Total coliforms	0.16
pH	0.11
Nitrates	0.1
phosphates	0.1
turbidity	0.08
sun. in suspension	0.07

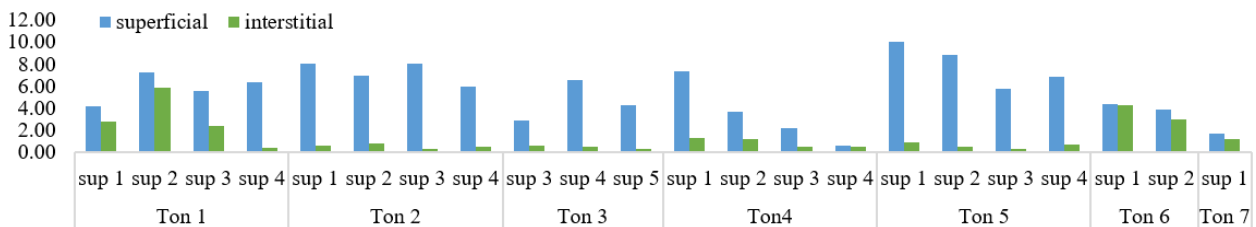


Figure 4. Surface vs. interstitial dissolved O₂ concentration comparison graph divided by plot (Ton) and subplot (sup)

After obtaining the result of the operation, this value is compared with the table of weighted weights for water quality variables (Figure 3) to determine the contamination level of the sample. The weighted weight represents the significance assigned to each measured variable, with some variables deemed more critical due to their environmental impact. This significance is encapsulated in their weighted weights.

Water Quality	Color	Rate
Excelent	Light Blue	91-100
Good	Light Green	71-90
Half	Yellow	51-70
Bad	Orange	26-50
Very Bad	Red	0-25

Figure 3. Colorimetric representation of values for water quality

The value table categorizes each level of water quality using a color code ranging from light blue to red, representing quality from excellent to very poor, respectively.

3. RESULTS AND DISCUSSION

The analysis of physicochemical variables, emerging contaminants, nutrients, and coliforms reveals significant anthropogenic influences from activities such as agriculture, livestock, and urban development. The results for the physicochemical variables are presented in descending order of importance, based on the weighted weights shown in Figure 4. All variables are shown in Table 3 (superficial water) and Table 4 (interstitial).

The concentration of dissolved O₂ is the highest in the importance table due to all the factors that can influence it such as temperature, pressure, solubility coefficient, salinity and physicochemical composition of water, therefore, it is a great indicator and comparative variable [1, 8, 22]. The greatest source of oxygenation is the contact of the water surface with the air and temperature is a fundamental factor for the solvency of O₂ in water [19, 22] The graph in Figure 5 shows the percentage of O₂ low and constant for the interstitial waters, on the other hand in Ton 7 there was almost no water so there was no observable flow and the water temperature was high from what can be seen a low percentage of dissolved oxygen.

pH is a measure of alkalinity/acidity, which is made up of measurements from the number 1 to 14 (in natural substances, but there are non-natural substances or concentrations that can exceed this measurement up or down). The normal pH of water has an average of 7.35 [22]. Anthropological activities have introduced inorganic compounds from livestock and agriculture, which greatly affect the pH level of a water column [15]. Figure 5 shows pH levels with little difference between surface and interstitial waters.

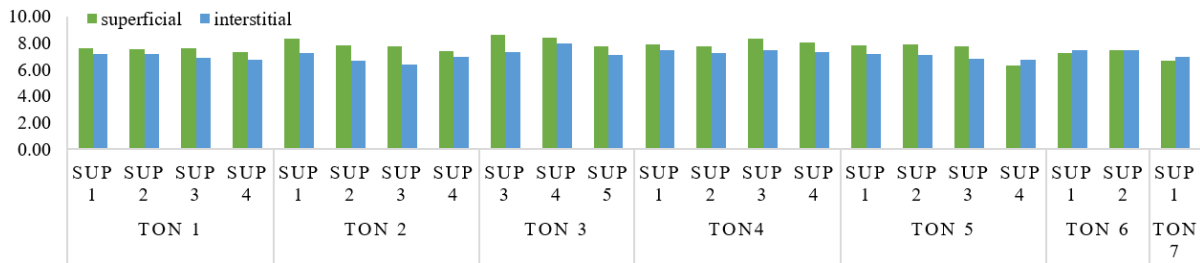


Figure 5. Comparison of the surface vs. interstitial pH level in the study plots

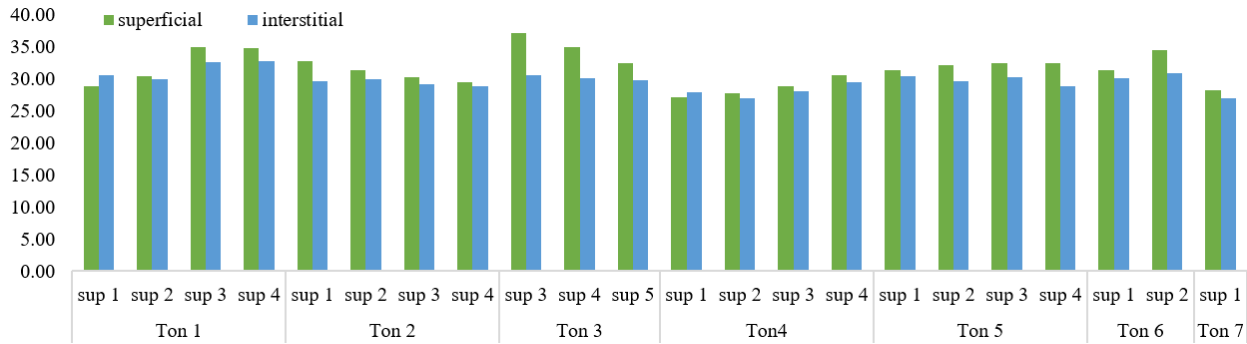


Figure 6. Averages of surface vs. interstitial temperatures in the study plots

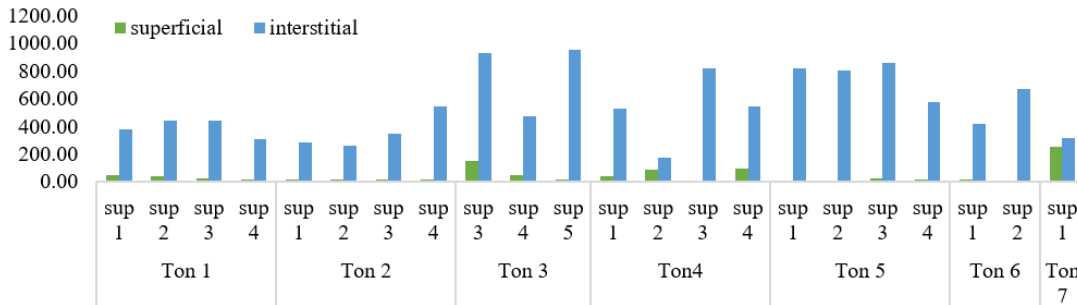


Figure 7. Comparative graph of turbidity of surface vs. interstitial water

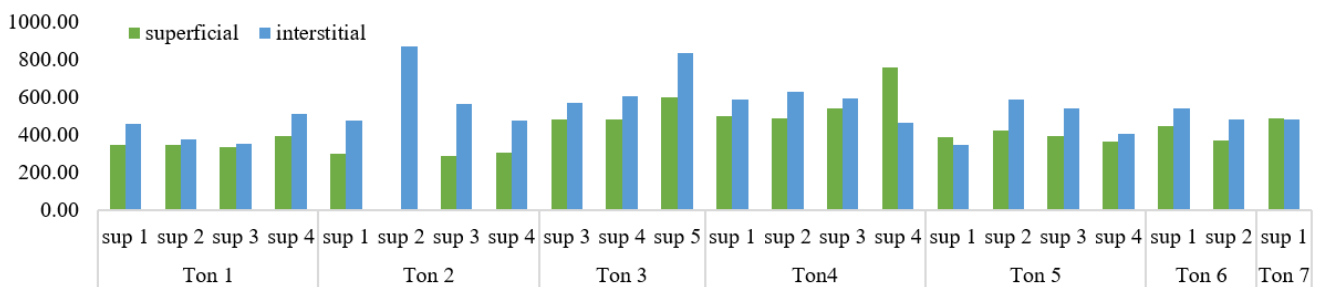


Figure 8. Comparative graph of suspended solids in surface vs. interstitial water

Temperature is one of the most relevant physical parameters for the analysis of water, since it affects other variables such as viscosity and the speed of chemical reactions [15]. The temperature averages obtained show a stable temperature with little variability in the plots. In general, these temperature ranges are normal in the tropical zone and typical of the tropical humid forest (refer to Figure 6).

Turbidity can be defined as the ability of the solid suspended within a column or tributary of water to block the passage of light. The causes of turbidity are multiple and varied. Among which we can mention: erosion (natural and/or anthropological source) and contamination by direct human activities such as constructions or excavations (anthropological) [15].

Turbidity is closely linked to the level of dissolved solids. Regarding its level in the surface water, we can see a very low level in most of the subplots with some points of rise not exceeding 200 nephelometric turbidity unit (NTU). With the exception of plot 7 where we can see a kind of convergence between the turbidity level of the surface water and the interstitial, due to the low amount of water that was present in the area (Figure 7).

Dissolved solids can be defined as any material that remains in a water sample once it is evaporated at more than 105°C, in other words, everything in a water sample that is not water [15]. In our study, the amount of dissolved solids ranged between values of 286.67 and 760.67 mg/L with a marked drop in subplot 2 of plot 3 where there was a more marked

water current than in the rest of the study area, on the contrary the rising peak of subplot 4 of plot 4 is due to a marked stagnation of water, so any movement such as sample collection created a rise of solids, Sierra Ramírez [14] ensure that agriculture has an impact in the amount of dissolved solids, however, plots six and seven (agricultural use) in our

study present levels similar to or lower than plots for livestock use. On the other hand, we can observe that the level of dissolved solids in the interstitial water is higher on average because, as described in the methodology, these samples were obtained after opening a hole in the wetland soil with the drilling hole. extraction of soil cores (Figure 8).

Table 3. Averages of the physicochemical and biological variables of surface water by plot and subplot, in Tonosí

Physical Chemical Parameter	Shallow Subplot	Superficial							
		Average t	Sun. in Suspension	Ph	Turbidity	O ₂ %	Coliforms	Nitrate	Phosphate
Ton 1	sup 1	28.77	349	7.61	43.07	4.17	5.67	0.9	14
	sup 2	30.4	348.67	7.52	35.3	7.19	5.67	0.9	14
	sup 3	35	337.33	7.57	21.63	5.55	5.67	0.9	14
	sup 4	34.7	393	7.32	19	6.35	5.67	0.9	14
Ton 2	sup 1	32.73	301	8.32	12.37	8	13540	4	13
	sup 2	31.37	2.72	7.82	14.77	6.89	13540	4	13
	sup 3	30.3	286.67	7.77	14.37	7.97	13540	4	13
	sup 4	29.5	308	7.4	12.93	5.89	13540	4	13
Ton 3	sup 3	37.07	480.33	8.61	151	2.88	87040	0.9	10
	sup 4	35	481	8.41	43.5	6.51	87040	0.9	10
	sup 5	32.4	602.67	7.73	11.6	4.23	87040	0.9	10
	sup 1	27.1	497.67	7.91	42.13	7.32	111990	0.9	4.75
Ton4	sup 2	27.8	486	7.78	88.03	3.68	111990	0.9	4.75
	sup 3	28.9	538.67	8.31	3.66	2.12	111990	0.9	4.75
	sup 4	30.6	760.67	8.07	91.63	0.55	111990	0.9	4.75
	sup 1	31.4	386.67	7.8	8.5	10.01	24810	0.9	3.26
Ton 5	sup 2	32.1	423.67	7.9	10.77	8.76	24810	0.9	3.26
	sup 3	32.5	396	7.73	22.73	5.71	24810	0.9	3.26
	sup 4	32.4	366.33	6.34	14.81	6.82	24810	0.9	3.26
	sup 1	31.4	449.67	7.21	12	4.34	58000	0.9	3.2
Ton 6	sup 2	34.4	369.67	7.43	4.06	3.84	58000	0.9	3.2
	sup 1	28.2	489.67	6.65	248.33	1.67	7170	5	eleven
units of measurement according to variable		T°C	mg/L	pH	NTU	%	NMP/100ml	mg/L	mg/L

Table 4. Average physicochemical and biological variables of interstitial water divided by plot and subplot, obtained in the Tonosí study area

Chemical Physical Parameter	Intercial Subplot	Interstitial							
		Average Temperatures	Sun. in Suspension	pH	Turbidity	O ₂ %	Coliforms	Nitrate	Phosphate
Ton 1	sup 1	30.50	458.00	7.21	377.60	2.77	5.67	0.9	14
	sup 2	30.00	378.67	7.21	442.33	5.79	5.67	0.9	14
	sup 3	32.60	355.00	6.91	442.33	2.33	5.67	0.9	14
	sup 4	32.80	512.33	6.76	308.00	0.39	5.67	0.9	14
Ton 2	sup 1	29.6	477.67	7.25	282.00	0.63	13540	4	13
	sup 2	29.9	871.33	6.68	258.00	0.80	13540	4	13
	sup 3	29.1	566.33	6.40	343.33	0.27	13540	4	13
	sup 4	28.8	475.67	6.93	545.00	0.49	13540	4	13
Ton 3	sup 3	30.6	570.00	7.31	930.33	0.54	87040	<1	10
	sup 4	30.1	604.67	7.95	473.33	0.5	87040	<1	10
	sup 5	29.8	835.00	7.10	952.67	0.24	87040	<1	10
	sup 1	27.9	589.67	7.46	530.00	1.32	111990	<1	4.75
Ton4	sup 2	27	631.67	7.23	170.00	1.17	111990	<1	4.75
	sup 3	28	596.67	7.46	815.67	0.45	111990	<1	4.75
	sup 4	29.4	466.67	7.29	542.33	0.46	111990	<1	4.75
	sup 1	30.4	348.33	7.16	821.33	0.84	24810	<1	3.26
Ton 5	sup 2	29.6	586.33	7.12	802.67	0.51	24810	<1	3.26
	sup 3	30.2	541.00	6.79	860.33	0.33	24810	<1	3.26
	sup 4	28.9	406.00	6.75	570.67	0.66	24810	<1	3.26
	sup 1	30.1	542.67	7.48	417.33	4.22	58000	<1	3.2
Ton 6	sup 2	30.8	480.33	7.48	672.67	2,955	58000	<1	3.2
	sup 1	27	485.00	6.99	313.67	1.15	7170	5	eleven
units of measurement according to variable		T°C	mg/L	pH	NTU	%	NMP/100ml	mg/L	mg/L

I. Water quality analysis for nitrate: The maximum amount of nitrate accepted as non-toxic is 50 mg/L to prevent the short-term toxic effect due to the production of methemoglobinemia, the standard established in your state is no more than 10 mg/L [29, 30]. The Complutense University of Madrid, tells us that uncontaminated water is around 4 mg/L, concentrations greater than this number could largely affect ecosystems because they favor an excessive increase in algae [30]. In the analyzes carried out on the plots, values lower than 1 mg/L are evident in four of the seven plots, however, plots 2 and plot 7 present 4 mg/L and 5 mg/L respectively, these values are not considered toxic and can occur naturally, but it should be noted that plot 7 presenting the highest concentration of nitrate has agricultural use by the population, which agrees with what was found in references [9, 14].

II. Phosphates: Under natural conditions, the concentration of phosphates in water is less than 1 mg/L; concentrations greater than this number could largely affect ecosystems because they favor an excessive increase in algae (eutrophication) [6]. The phosphate levels obtained in the samples are worrying and demonstrate a high level of anthropological influences in the sampling area, Sierra Ramírez [14] found results superior to those found in our study area, the study [9] obtained more similar results to ours but they come to the conclusion that these are due to the activities identified as grazing animals, wastewater discharge and cultivation, all of these activities carried out in the area. The study [9] mentions that in the tropics phosphorus is consumed very quickly, therefore the only way in which an increase is noticeable is if there is anthropological intervention. Under normal conditions, as was already clear in the explanation part of each measured compound, the normal level of Phosphates in the environment is less than 1 mg/L, so the effect of anthropological contamination in this first area of the study is undoubted. The highest concentration of phosphates occurs in plot one with a value of 14 mg/L, followed by plots two and seven with concentrations of 13 and 11 mg/L respectively.

Figure 9 shows us the difference in the concentrations of both nutrients, the mostly normal level of nitrate is a clear contrast to the abnormal quantities in the present of phosphates.

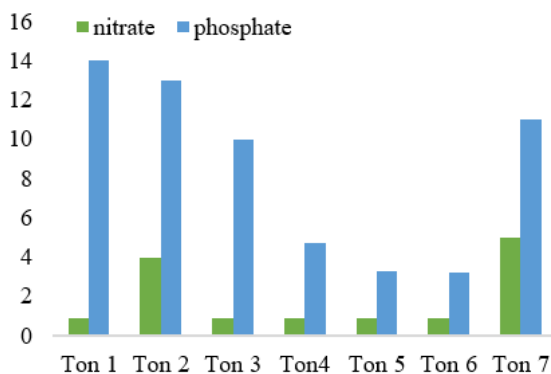


Figure 9. Comparison of nitrate and phosphate per plot in the study area, Tonosí

III. Coliform analysis: Coliforms are a type of bacteria which are present in tributaries contaminated by fecal material, which is why they are of significant importance as pollution indicators [21]. The permissible limits established by Water Law 75 for Panama for the recreational use of water sources is ≤ 250 bacteria/100ml for wastewater), according to the

national standards of Costa Rica, the maximum permissible limit is ≤ 1000 bact/100ml [13]. As is shown in the Figure 10 all sampled plots presented harmfully high bacterial indices ranging from 13,540 bact/100ml to 111,990 bact/100ml; With the exception of plot 1, it had a bacterial presence of 5670 bact/100ml. Researchers [9] found similar results in their sampling, where they highlight that the abundance of this biological marker is due to a discharge of fecal matter. Sierra Ramírez [14] focused on fecal coliforms, but reached the same conclusion. especially giving rise to anthropological activities carried out in the study area. It should be noted that according to Panamanian Commission of Industrial and Technical Standards (COPANIT), all these samples are dangerously harmful if this water is used for human consumption.

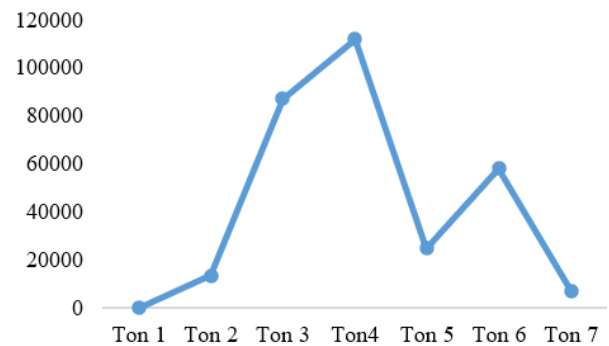


Figure 10. Total coliforms detected in the plots in the study area, Tonosí (NMP/100ml = bact/100ml)

IV. Analysis of agrochemicals: Agrochemicals are multiple substances used for different situations of plant or animal pests, whose effects and concentrations will be detailed one by one. Most of the plots presented low but existing concentrations of Chlorpyrifos and Ethoprofos (plots 1, 2, 3 and 7), plot 2 was the most contaminated with the presence of multiple agrochemicals in different concentrations. Plots 4 and 5 did not present any concentration of agrochemicals; It should be clarified that this does not mean that they have not been contaminated, but rather that they were not seen during the sampling period. Even so, it is considered that they may be contaminated. Agrochemicals present in the sampling area [9, 31].

All detected agrochemicals are presented in this table. Within which some results are shown with < 0.14 those that were detected, but in smaller quantities than those measured precisely. On the other hand, the “-” show that these agrochemicals were not present in the plots. The table shows us a clear and significant presence of agrochemicals in plot 2.

Chlorpyrifos: synthetic compounds or components not found in the nature. Depending on the amount or time of exposure, both breathing and ingesting these compounds can cause various negative effects on the nervous system, such as headaches, vision problems, seizures with salivation, coma or even death. In the plots in which this agrochemical was present, it occurred in concentrations lower than $0.14 \mu\text{g/L}$, which is not considered harmful to human health [9, 32].

Ethoprofos is a synthetic nematicide which is not naturally present in nature. This has a moderate solubility in water and a low resistance in soil. Highly toxic to aquatic organisms. For this study, the concentrations were also low in most cases at $0.14 \mu\text{g/L}$, which is not considered harmful [9, 32, 33].

Bifenthrin: it is a synthetic insecticide, it has low solubility in water, but high resistance in the soil, its toxicity is very high

in invertebrate organisms such as crustaceans and medium in others such as birds [9, 34]. Its concentration in plot 2 was 0.29 µg/L, which is considered low [18] It should be noted that this was analyzed in water but not in soil, so it may be in higher concentrations than expected.

DDD and DDE: are synthetic compounds that are not present in nature which are derived from the agrochemical Dichlorodiphenyltrichloroethane (DDT), which is prohibited for sale. They are not biodegradable, they have a low solubility in water, but their resistance in soil is considered extreme. They are especially toxic to crustaceans and fish [9, 35]. In Central America and other parts of the world, a concentration of <1 µg/L is considered the maximum allowed to be considered non-toxic. These compounds are presented in the analysis of plot 2. They were present in the analyzes of plot 2 in amounts of 0.193 µg/L of DDD and concentrations <0.14 µg/L of DDE, which is not considered toxic and does not occur in the rest of the plots.

Etofenprox: are synthetic compounds that are not present in nature. Its solubility and resistance in soil are very low. However, they are especially toxic to aquatic organisms [9, 36], the European Union considers the limit of <1 µg/L as non-toxic. In our study it was found in plot 2 with a concentration of <0.14 µg/L in plot 2.

Metolachlor: synthetic herbicides that do not occur in nature. Highly toxic to aquatic organisms, its solubility is high and its resistance in the soil is low [9]. Concentration in plot 2 (the only plot in which it was present according to the analysis) of <0.14 µg/L, somewhat lower than the maximum set by Holland of <0.2 µg/L.

Mirex: Low water solubility and zero soil resistance. It is a compound present in multiple types of pesticides [9]. Its concentration in plot 2 (the only plot in which it was present

according to the analysis) is <0.14 µg/L.

Pirimicarb: Synthetic pesticide compound with high solubility and extreme soil resistance. High toxicity for aquatic organisms [9, 25]. Maximum limits in Europe are <0.9 µg/L. Concentration in plot 2 (the only plot in which it was present according to the analysis) of <0.14 µg/L.

Terbuthylazine: synthetic herbicide compound, which solubility is low and its resistance in the soil is extreme. It is present in a high number of pesticides and according to European standards a maximum of <0.9 µg/L is considered [9]. High toxicity for aquatic organisms. Concentration in plot 2 (the only plot in which it was present according to the analysis) of <0.14 µg/L.

As we have observed, the two most frequently found agrochemicals with the clear exception of plots 4 and 5 are chlorpyrifos and ethoprosfos which were explained at the top of the document (Table 5). Plot 2 was the one with the greatest abundance of agrochemicals, but their actual concentrations (for many) were lower than what the laboratory equipment could measure. Furthermore, many of these agrochemicals, as mentioned in their explanations, have low solubility and high resistance in the soil, so it is not clear if these were used recently in low concentrations or if they were used a long time ago in high enough concentrations. enough to be measured to this day.

Ethoprosfos: The most worrying group of chemicals, their presence in plot 6, although notable, does not have a concentration high enough to be dangerous, plots 3 and 7 where concentrations of 224 and 221 respectively are seen, which is considered as they can be toxic. These concentrations are much higher than what is accepted (1 µg/L) for human use and contact in most countries.

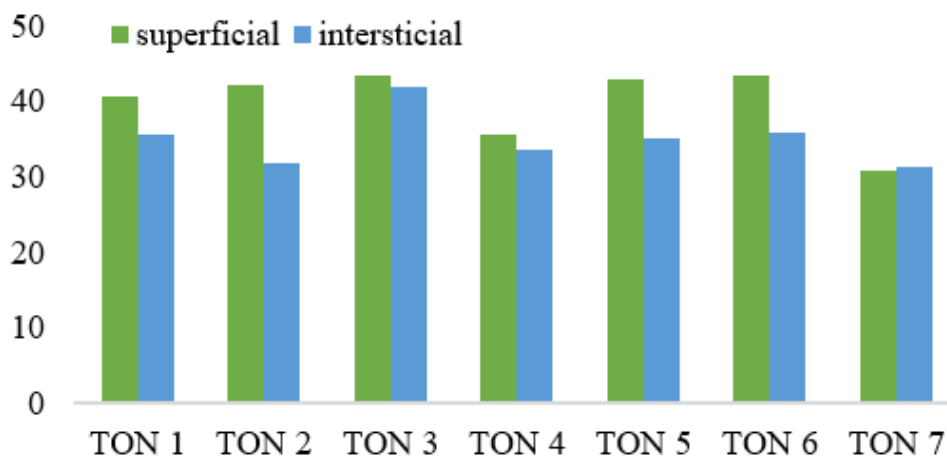


Figure 11. Comparative graph of WQI values per surface vs interstitial plot

Table 5. Agrochemicals present in each plot of Tonosí

Agrochemicals	TON 1	TON 2	TON 3	TON 4	TON 5	TON 6	TON 7	Units
Chlorpyrifos	<0.14	<0.14	<0.14	-	-	0.187	<0.14	µg/L
Ethoprosfos	<0.14	<0.14	224	-	-	0.283	221	µg/L
Bifenthrin	-	0.29	-	-	-	-	-	µg/L
DDD	-	0.193	-	-	-	-	-	µg/L
DDE	-	<0.14	-	-	-	-	-	µg/L
Etofenprox	-	<0.14	-	-	-	-	-	µg/L
Metolachlor	-	<0.14	-	-	-	-	-	µg/L
Mirex	-	<0.14	-	-	-	-	-	µg/L
Pirimicarb	-	<0.14	-	-	-	-	-	µg/L
Terbuthylazine	-	<0.14	-	-	-	-	-	µg/L

Table 6. Results of the WQI calculation of surface water by plot and subplots in the Tonosí study area

Parcel/Subplot	TON 1	TON 2	TON 3	TON 4	TON 5	TON 6	TON 7
Use of the Plot	Cattle Raising	Cattle Raising	Cattle Raising	Cattle Raising	Cattle Raising	Agricultural	Urban/Agricultural
Sub 1	40.365	39.889		38.36	44.23	42.23	30.5
Sub 2	41.964	43.305		35.1	42.605		
Sub 3	42.54	41.97	38.755	39.335	42.99		
Sub 4	42.65	40.025	44.025	39.117	39.247		
Sub 5			48.59				
Sub 6						45.47	
General	41.22	42.105	44.104	35.34	43.271	43.89	30.5

Table 7. Results of the calculation of WQI of interstitial water by plot and subplots in the Tonosí study area

Parcel/Subplot	TON 1	TON 2	TON 3	TON 4	TON 5	TON 6	TON 7
Use of the Plot	Cattle Raising	Cattle Raising	Cattle Raising	Cattle Raising	Cattle Raising	Agricultural	Urban/Agricultural
Sub 1	36.715	33.187		32.865	37.185	35.61	30.5
Sub 2	37.593	31.564		33.545	33.245		
Sub 3	36.88	29.727	42.302	31.017	34.511		
Sub 4	33.8263	30.224	41.362	33.137	34.677		
Sub 5			42.162				
Sub 6						36.55	
General	36.44	31.564	42.079	33.074	34.754	35.87	30.5

Note: For color quality, refer to Figure 3

3.1 Analysis of the water quality index

To assess water quality, the NSF WQI was utilized, employing common, easily measurable physicochemical parameters to evaluate the impact of anthropogenic activities on the wetland. The parameters used included water temperature, total coliforms (substituting for fecal coliforms), suspended solids, pH, turbidity, and dissolved oxygen percentage.

The analysis of WQI results across the study area revealed uniformly poor ratings for the Tonosí coastal wetlands across all plots. Specifically, the results from plot 7, which had low water levels, may not accurately reflect the full extent of contamination due to its limited sample size. This study links the usage of each plot and the resultant anthropogenic impacts to the observed levels of contamination and the evident degradation of the wetlands. As depicted in Figure 11, the WQI behavior can also be attributed to seasonal factors such as water scarcity and higher temperatures during the dry season, which typically result in reduced water flow, increased turbidity and dissolved solids, and decreased oxygen levels.

4. CONCLUSIONS

The NSF WQI focuses on basic physicochemical and biological parameters, it does not take into account other influences such as emerging contaminants or phosphates and nitrates for its evolution, however, as has been made clear throughout the study that the influence of anthropic activities on water quality in the Tonosí wetlands cannot be denied.

The poor quality of the water is a reflection of bad practices in the management of anthropological activities that take place around the study area. The principal variables that influenced the WQI result to be “bad” are: the high amount of phosphates, extremely low level of oxygen and the very high amount of coliforms.

The inappropriate use of agrochemicals is seen in the results obtained in which their presence was detected either for the control of pests or herbicides or in the nutrient levels recorded in the waters.

This study provides the base to compare further studies of

water quality in fresh water coastal wetland in Panama. We recommend the elaboration of a WQI that includes the presence of agrochemical components for application in this type of cases.

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