



## Tools for managing water quality from trophic state in the estuarine system Cienfuegos bay (Cuba).

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**Abstract:** This paper contributes to the coastal environmental management by proposing some tools for managing water quality from trophic state, in Cuban bays with estuarine characteristics. Although eutrophication-like symptoms have been previously reported in Cuban semi-enclosed bays with estuarine characteristic, there is no specific methodology for managing this environmental problem. In this study, we propose a conceptual model of water quality management from trophic state for these aquatic systems and the methodology for implementing it supported on indicators according to the Driver–Pressure–State–Impact–Response (DPSIR) approach. As a case study, the Cienfuegos bay is presented and the stages of this methodology are carried out in order to test its feasibility as a tool for managing the eutrophication. The results obtained were favorable and showed the importance of assimilating systemic and causal approaches in this environmental management proposal.

**Keywords:** eutrophication, methodology, management, bay

**Resumen:** Herramientas para manejar la calidad del agua a partir del estado trófico en el sistema estuarino bahía de Cienfuegos, Cuba. Este trabajo contribuye a la gestión ambiental costera mediante la propuesta de algunas herramientas para manejar la calidad del agua desde el punto de vista trófico en bahías cubanas con características estuarinas. Aunque se han reportado síntomas de eutrofización en bahías cubanas semicerradas con características estuarinas, no existe una metodología para manejar este problema ambiental. En este estudio proponemos un modelo conceptual de gestión de la calidad del agua desde el punto de vista trófico para estos sistemas acuáticos y la metodología para su implementación apoyada en indicadores de acuerdo a la aproximación Fuerza conductora-Presión-Estado-Impacto-Respuesta (FPEIR). Como un estudio de caso se presenta la bahía de Cienfuegos y se llevan a cabo las etapas de esta metodología en función de probar su factibilidad como herramienta para manejar la eutrofización. Los resultados obtenidos fueron favorables y mostraron la importancia de asimilar los enfoques causal y sistémico en esta propuesta de gestión ambiental.

**Palabras clave:** eutrofización, metodología, manejo, bahía

### Introduction

Eutrophication of estuarine systems is a widespread environmental problem (Bricker *et al.* 2003, Nixon 2009, Cook *et al.* 2010). Consequences of eutrophication include fish deaths and significant economic losses (Schernewski *et al.* 2009, Loza *et al.* 2013, Moreira *et al.* 2014)

The most commonly used tools supporting the environmental management of eutrophication (*e.g.*

Bricker *et al.* 2003, Vollenweider *et al.* 1998) only contribute to the diagnosis stage. The integrated methodology for the Assessment of Estuarine Trophic State (ASSETS) proposed by Bricker *et al.* (2003) is one of them and it is based on pressure-state-response (PSR) indicators. However, this methodology lacks of the needed systemic approach to guarantee the integration among the implicated stakeholders (Gari 2010, De Jonge *et al.* 2013). It

also needs to consider the drivers for supporting the selection of proper management strategies as well as tools for evaluating them (Whitall *et al.* 2007).

The systemic and causal approaches are considered to address eutrophication in several countries (Zaldivar *et al.* 2008, Gari 2010, Garmendia *et al.* 2012). The second approach based on the Driver–Pressure–State–Impact–Response (DPSIR) indicators, links the human driving forces, the causes of alteration in the ecosystem (pressures), the state of the ecosystem, the effects of changes in state (impacts) and the management strategies (response). When considering these approaches and the risk analysis, it is possible to obtain a useful tool for reducing the eutrophication risk in the ecosystem (Garmendia *et al.* 2012, Cormier *et al.* 2013). The risk analysis is an important aspect for managing this environmental problem from a preventive point of view, and yet it has been hardly used.

In some studies about eutrophication in the Caribbean and Latin-America region (López-Cortés *et al.* 2003, Herrera-Silveira *et al.* 2011, Alves *et al.* 2013, Montalvo *et al.* 2014), different indexes were applied for assessing trophic state. Most of these studies used the index TRIX, proposed by Vollenweider *et al.* (1998) and the ASSETS method (Bricker *et al.* 2003).

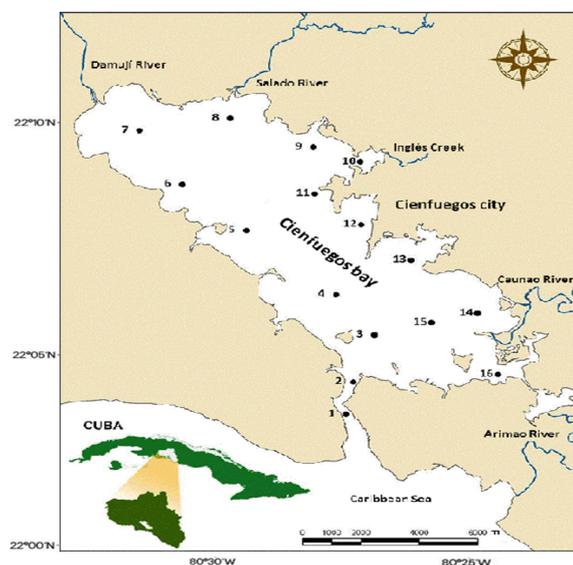
In Cuba, some studies have reported eutrophication-like symptoms in semi-enclosed bays with estuarine characteristics, such as high chlorophyll *a* levels and toxic algal blooms events (Gómez *et al.* 2006, Reyes 2008, Moreira *et al.* 2014), though hitherto without a specific methodology for managing this environmental problem.

Cienfuegos bay is one the Cuban bays that has showed deleterious effects, like loss of biodiversity, high nitrogen levels and toxic algae blooms events (Moreira *et al.* 2006, Seisdedo *et al.* 2009, Helguera *et al.* 2011, Moreira *et al.* 2014). This estuarine system is impacted by the polluting discharges of Cienfuegos city and the nearby agricultural and industrial zones. Even though this system shows as average non-eutrophic water condition (Seisdedo *et al.* 2014), the level of nutrient loads can still be high in some areas and increase into the future without applying an appropriate management methodology.

Consequently, we apply causal (DPSIR) and systemic approaches in order to manage water quality based on the eutrophication risk analysis and taking into account the unique characteristics of the estuarine system Cienfuegos bay.

## Materials and methods

**Study area:** Cienfuegos bay is situated in the southern central part of Cuba (22°1' N, 80°20' W, Figure 1). It is a semi-enclosed bay with estuarine characteristic. It is connected to the Caribbean Sea by a narrow channel 3.6 km long. Its area is 88.46 km<sup>2</sup> and a total volume of 0.84 km<sup>3</sup> with an average depth of 9.5 m (Muñoz *et al.* 2012). Its coastal line represents the most important natural resource in the Cienfuegos province, due to fishing (6%) and industrial activities (7%), agriculture (2%), maritime transport (7%), natural parks (70%), urbanization and tourism (8%) (Moreira *et al.* 2014). The bay is divided into two natural lobes. The northern lobe has more anthropogenic impact: e.g. sewage discharges from the city of 161,432 inhabitants (ONEI 2012) and the incidence from industrial area. There is also freshwater input from the Damují and Salado rivers and from other less extensive river basins such as El Inglés, Calabazas and Manacas creeks. In this region, despite actions by the local government to reduce pollution in the bay, the wastewater treatment is still inadequate. The southern lobe is subjected to a lesser degree of pollution arriving from the Caonao and Arimao rivers.



**Figure 1.** Localization map of Cienfuegos bay, Cuba and sampling stations.

Weather conditions in the study area can be divided into two seasons: dry (November–April) and rainy (May–October) seasons. The bay has marked vertical haline stratification, caused by runoff from land and low tidal mixture (Moreira *et al.* 2014).

*Conceptual model of water quality management*

from trophic state for estuarine systems: Models and support methodologies related to the environmental management of eutrophication with causal and systemic approaches were consulted (Bricker *et al.* 2003, Whittall *et al.* 2007, Gari 2010, Garmendia *et al.* 2012, Cormier *et al.* 2013, Butler *et al.* 2013) for defining the principles, main characteristics of this model and indicator categories.

In order to test these aspects, expert criteria were considered by the Delphi method (Bravo & Arrieta 2005). The determination of expert number was based on the method proposed by García & Fernández (2008), then nine experts with a high competition degree were consulted using questionnaires. The association among the answers was tested by Kendall Coefficient of Concordance (Legendre 2005) using the statistical package SPSS for Windows version 15.0. The qualifications of the principles, characteristics and indicator categories were based on a value scale: 1-indispensable, 2-very necessary, 3-necessary, 4-not very necessary and 5-not necessary.

*Methodological proposal of water quality management from trophic state for estuarine systems:* Firstly, it was needed to design the diagnosis and evaluation tools for supporting the methodology of water quality management from trophic state for estuarine systems. This step required the selection of indicators according DPSIR, which was developed by means of two phases: qualitative and testing. For the first one, different indicator proposals in the methodologies consulted (USEPA 2001, Bricker *et al.* 2003, Cardoso & Carmona 2004) were considered. The testing phase required using expert criteria by the Delphi method, which allowed:

- to evaluate the indicator quality considering: relevancy, availability, simplicity, objectivity and using a scale from 1 to 10 (up to the biggest).
- to evaluate the indicator suitability, based on the categories: very suitable (1), quite suitable (2), suitable (3), not very suitable (4) and not suitable (5).
- to determine the degree of the experts' agreement by means of the Kendall coefficient (W).
- to validate the indicators correlating the values of indicator quality and suitability by means coefficient Rho of Spearman.
- to evaluate the sensitiveness of each proposed indicator using Vester matrix according to García (2013).

The evaluation scale of indicators, proposed by García (2013), was used as follows: excellent

(0.76 - 1), good (0.51 - 0.75), regular (0.26 - 0.50) and bad ( $\leq 0.25$ ). This scale was based on the classification criteria for each indicator defined by the expert group considering some proposals in the methodologies consulted (Bricker *et al.* 2003, García 2013, Seisdedo & Muñoz 2013). In particular, for the indicator related to nutrient loads from river, the classifications of Water Quality Index (WQI) applied to Cienfuegos bay (Seisdedo & Muñoz 2013) was used, since it considered freshwater discharge as the main nutrient source to this system (Seisdedo & Arencibia 2010). This index considers causal and response parameters ( $\text{NH}_4^+$ ,  $\text{NO}_2^-$ ,  $\text{NO}_3^-$ ,  $\text{PO}_4^{3-}$ , Biochemical Oxygen Demand, chlorophyll *a*) related to eutrophication and the combining method proposed by CCME (2001):

$$ICA = 100 - \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1,732}$$

where:

F<sub>1</sub>- parameter quantity with not fulfilled quality criteria

F<sub>2</sub>- how many times are not fulfilled the quality criteria

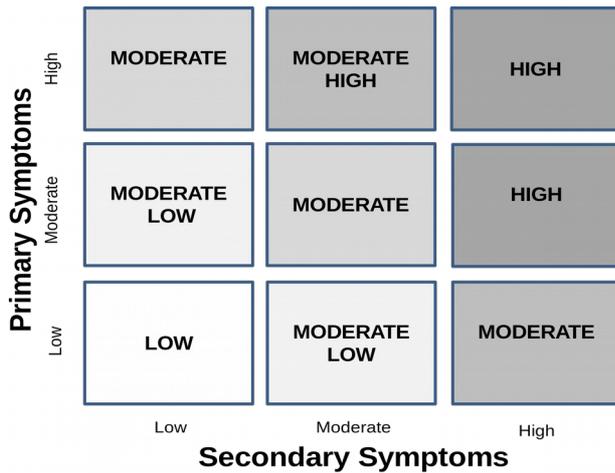
F<sub>3</sub>- result deviations with not fulfilled quality criteria

It was also considered the eutrophication risk analysis for the diagnosis, from assessing the pressure, trophic state and environmental impacts.

*Assessing pressure:* In order to define the pressure indicator related to system assimilation capacity and its classification criteria, the degree of the experts' agreement by means of the Kendall coefficient (W) was determined. For this, some data reported previously (Pérez *et al.* 2008, Seisdedo & Arencibia 2010, Muñoz *et al.* 2012) on two Cuban estuarine systems (Cienfuegos and Havana bays) with different trophic state classifications according to Reyes (2008) and Seisdedo *et al.* (2014), were considered for a comparative analysis. The selection of these systems was based on the similarity in some aspects (*e.g.*, morphology, temperature and salinity variability, stratification, uses and quality objectives) as proposed Cardoso da Silva (2002).

*Assessing trophic state:* For the trophic state indicators selected, we considered the same criteria proposed by Bricker *et al.* (2003) in the ASSETS method, as well as its matrix for assessing eutrophic condition based on evaluation of the primary and secondary symptoms.

For assessing the environmental impacts related to eutrophication, the matrix proposed by Pérez (2013) was considered (Figure 3).



**Figure 2.** Matrix for assessing eutrophic condition proposed in the ASSEST method (Bricker *et al.* 2003)

For this methodology, four main stages (to prepare, to plan, to implement, and to control - evaluate) were considered. Different methodologies related to the environmental management of eutrophication with causal and systemic (Bricker *et al.* 2003, Whitall *et al.* 2007, Gari 2010, Garmendia *et al.* 2012, Cormier *et al.* 2013, Butler *et al.* 2013), the cycle proposed in the ISO 14001 (2015), as well as the structure and functions of the Management Authority proposed by the Integrated Coastal Management Group in Cuba (CITMA 2015) were taken into account.

*Application of the methodological proposal for managing water quality from trophic state in Cienfuegos bay:* Stage I (To prepare): In order to prepare the basic conditions for carrying out the stages of this methodology; it was needed to define the objective of this research, the reference framework and the entity in charge of testing the feasibility of this methodological proposal. Some participative workshops and discussion meetings were required for achieving the stakeholders engagement and commitment (i.e, government,

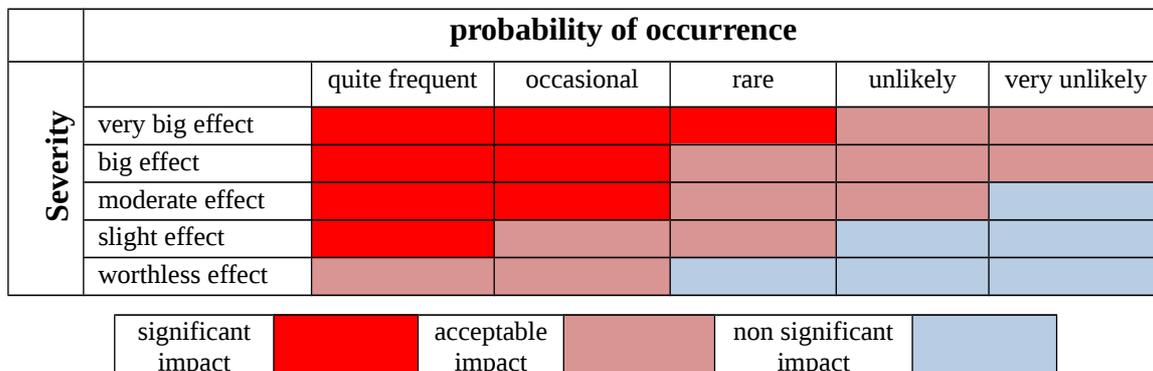
communities, educational, scientific and polluting entities), as well as to build abilities and to systematize the knowledge related to this methodology.

Stage II (To plan): It was needed the collaboration of different entities of the province to get access to the data required for the diagnosis. One of the main contributors was the Centro de Estudios Ambientales de Cienfuegos (CEAC), which is in charge of the monitoring program for assessing the water quality of Cienfuegos bay and its polluting loads. Data was also gathered from other entities related to the environmental management in the Cienfuegos province. Furthermore, some members of CEAC, defined by the Management Authority, carried out the evaluation of indicators and the eutrophication risk analysis using the tools designed for this purpose.

For analyzing the priorities, the percentages of nutrient loads from different sources (rivers, polluting entities, sewer drainages, atmospheric contribution) were considered. Some data related to the atmospheric contribution and polluting entities were obtained from previous assessments (Seisededo & Arencibia 2010).

Stage III (To implement): It was also needed to verify the human, materials and financial resources, through a participative workshop with the stakeholders, in order to design the preventive or corrective actions for the improvement of the water quality from trophic state.

Stage IV (To control-evaluate): The degree of action execution was monitored monthly by some representative groups of controlling entities. In order to evaluate the changes generated by the application of this methodology, the results of the selected indicator corresponding to before and one year after implementing the methodology were compared by means of the significant differences among them using the non-parametric Wilcoxon test.



**Figure 3.** Matrix for assessing environmental impacts proposed by Pérez (2013)

Trophic state/ Impact	Pressure		
	Low	Moderate	High
Low/ Non significant	Without risk	Without risk	With risk
Moderate-Low/ Non significant	Without risk	With risk	With risk
Moderate/Acceptable	With risk	With risk	With risk
Moderate-High/Acceptable	With risk	With risk	With risk
High/Significant	With risk	With risk	With risk

Figure 4. Matrix for analyzing the eutrophication risk proposed by Simón *et al.* (2013)

*Testing the feasibility of the proposed methodology application in Cienfuegos bay:* The Technique Iadov (López & González 2002) was applied by means of a questionnaire and the group satisfaction index was obtained. Thirteen stakeholders, most of members of Authority for the environmental management of Cienfuegos bay, were selected considering the possibilities of offering more information.

## Results

*Conceptual model of water quality management from trophic state for estuarine systems:* The principles, main characteristics and indicator categories selected by the expert group are shown in Table I. These aspects were evaluated as average of very necessary and the values of Kendall coefficient (W) and significance obtained ( $p < 0.05$ ) showed an appropriate association degree in the expert criteria.

The model objective is to provide a conceptual framework for the environmental management, contributing to the improvement of water quality from trophic state in Cuban estuarine systems. Starting from recognizing the inadequate way of managing water quality from trophic state, due to it was not supported on tools with systemic and causal (DPSIR) approaches. Our environmental management proposal requires the following stages: preparation, planning, implementation and control-evaluation. Moreover, it considers the participative conception from the analysis and deliberation among

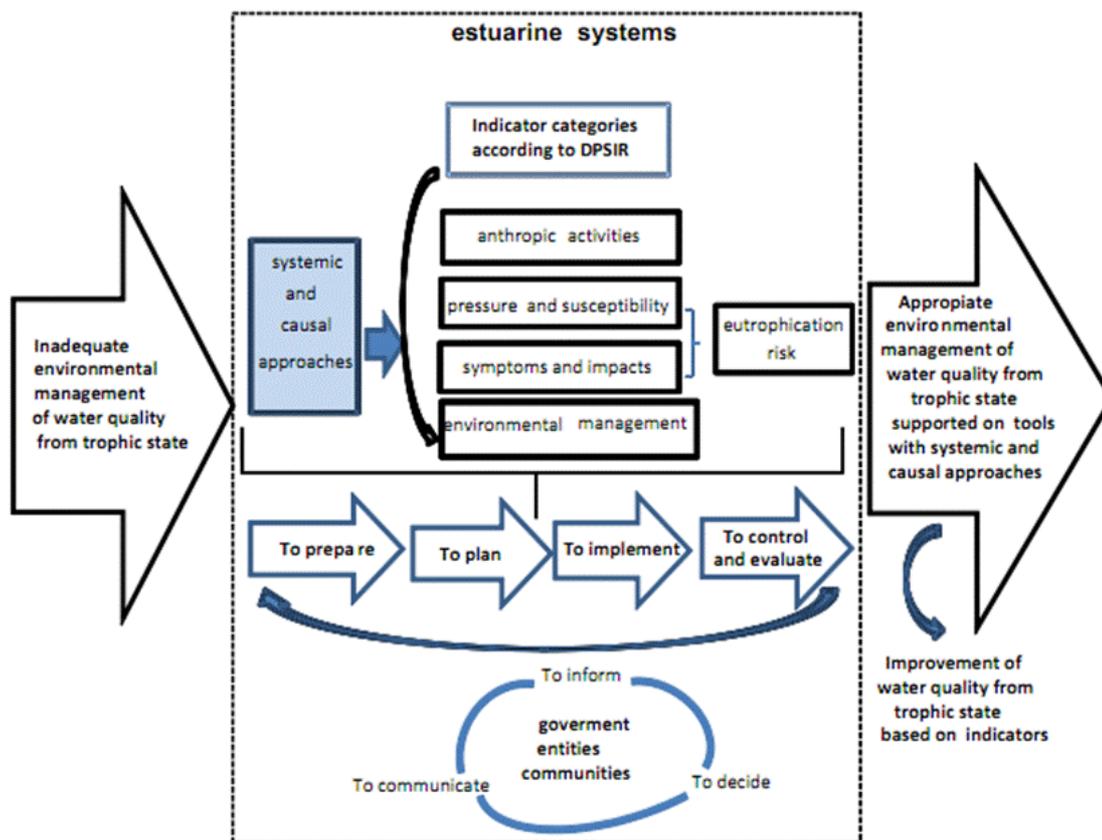
the stakeholders.

*Methodological proposal of water quality management from trophic state for estuarine systems:* For the diagnosis and evaluation tools of this methodological proposal, high qualifications were obtained (larger than 7) in the evaluated qualities for ten of fourteen indicators proposed. Also, the results from the Vester matrix showed as sensitive indicators only those with high quality values and the obtained value of Kendall coefficient was 0.624 ( $p < 0.05$ ) showing an appropriate degree of the experts' agreement. The value of coefficient Rho of Spearman (0.93) allowed validate the indicators selected (Table II).

The expert group recognized important susceptibility aspects and nutrient (nitrogen and phosphorus) loads for the pressure indicator. The comparative analysis of the susceptibilities for both selected Cuban bays showed classifications Moderate-High based on analysis of dilution, exporting and stratification criteria (Cardoso & Carmona 2004). This result allowed considering as a better pressure indicator the excess potential of nutrient assimilation capacity including dilution capacity and nutrient loads as the proposal (USEPA 2001). The Kendall coefficient values showed an appropriate degree of the experts' agreement for selecting this indicator ( $W = 0.56$ ,  $p < 0.05$ ) and for defining its threshold corresponding high pressure from  $\geq 10 \times 10^{-8}$  ton/m<sup>3</sup>d ( $W = 0.89$ ,  $p < 0.05$ ).

Table I. Principles, model characteristics and indicator categories selected and the results of association degree in the expert criteria on these aspects.

Aspects	Principles	Characteristics	Indicator categories
	-Causal approach -Systemic approach -Continuous improvement -Based on facts -Participative	-Integrated -Preventive -Relevancy -Based on context -Logical consistency	-Anthropic activity -Pressure and susceptibility -Symptoms and impacts -Management actions
Mean	2,05	1,98	2,00
W	0,560	0,613	0,571
Sig.	0,000	0,001	0,002



**Figure 5.** Conceptual model of water quality management from trophic state for estuarine systems. Own elaboration

**Table II.** Average qualifications for selected indicators

Indicators (DPSIR)	Suitability	Quality
Deforestation (Def)	3	7.5
Population without sewer treatment system (Pop)	2	8.25
Nutrient loads from rivers (Riv)	2	8.5
Excess potential of nutrient assimilation capacity (Exc)	3	7.75
Expression of chlorophyll <i>a</i> (Chl <i>a</i> )	1	9.25
Expression of bottom dissolved oxygen (DO)	1	9.5
Occurrence of toxic algal blooms (TAB)	1	8.25
Affectation of aquatic organisms (Aff)	3	7
Percentage of environmental strategies (Env)	2	7.25
Percentage of environmental action execution (Act)	2	7.75

The trophic state indicators selected were the bottom dissolved oxygen and chlorophyll *a* expressions, and the occurrence of toxic algal blooms (Table II)

Although the occurrence of toxic algal blooms was considered as a secondary symptom in the methodology ASSETS, we assumed it as primary symptom taking into account the coastal eutrophication conceptual model, phase II (Cloern

2001).

As two primary symptoms were included in this study, the largest value of them was considered for the general assessment based on the preventive principle and the matrix (Figure 2) proposed by Bricker *et al.* (2003).

The evaluation criteria proposed by the expert group for each selected indicator is shown in Table III.

**Table III.** Formula and evaluation criteria for the selected indicators

Indicators	Bad (0,25)	Regular (0,50)	Good (0,75)	Excelent (1)
Def=100-BIP/BIN x 100 BIP: forestry index at province level BIN: forestry index at nation level	Def >50 %	25 % ≤ Def ≤ 50%	10 % ≤ Def ≤ 25 %	Def <10 %
Pop =PST/PT x 100 PST: population without sewer treatment PT: population total with incidence	Pop>50 %	25 % ≤ Pop ≤ 50%	10 % ≤ Pop ≤ 25 %	Pop<10 %
Riv =Σ (NLR <sub>i</sub> ) NLR <sub>i</sub> : nutrient (N+P) load from each river	WQI classification (mediocre – bad)	WQI classification (moderate)	WQI classification (acceptable)	WQI classification (excelent)
Exc = NL/V NL: total nutrient (N+P) load incorporated to the system V: total volumen of the system	High Exc.	Low Exc. with some eutrophic symptom in more than a half of the system area	Low Exc. with some eutrophic symptom in less than a half of the system area	Low Exc. without any eutrophic symptom
Chla	hypertrophic system often	High expression	Moderate expression	Low expression
DO	High expression	Moderate expression	Low expression	All system with DO>5 mg/L often
TAB	High expression	Moderate expression	Low expression	None TAB
Aff.	With significant impact	With acceptable impact	With non significant impact	With none affectation
Env=PES/PE x100 PES=Number of polluting entities without environmental strategies PE=Number of polluting entities	Env >50 %	25 % ≤ Env ≤ 50%	10 % ≤ Env ≤ 25 %	Env <10 %
Act=EA/TEA x100 EA=not fulfilled environmental actions TEA= total number of environmental actions	Act >50 %	25 % ≤ Act ≤ 50%	10 % ≤ Act ≤ 25 %	Act <10 %

*Application of the methodological proposal for managing water quality from trophic state in Cienfuegos bay:*

Stage I (To prepare): The defined general objective consisted on developing an effective environmental management of water quality from trophic state in Cienfuegos bay. Then, it was achieved the commitment of all members of the Management Authority of Cienfuegos bay, which is represented by the stakeholders (government, communities, educational, scientific and polluting entities) working systematically since 2013. Consequently, participative workshops were the way used to develop the abilities required for carrying out the methodology, where the set of indicators were also transferred to the implicated stakeholders.

Stage II (To plan): The diagnosis was carried out using the data obtained:

The calculation of the pressure indicator based on the excess potential of the nutrient assimilation capacity was  $0.9 \times 10^{-8}$  ton/m<sup>3</sup>d before applying the methodology, which showed a not high pressure.

The results for the chlorophyll *a* concentration corresponding to period 2009-2013 (before applying this methodology) showed moderated and low expressions for rainy and dry seasons, respectively, according to the criteria in ASSETS method (Bricker *et al.* 2003).

The results of dissolved oxygen concentration at bottom corresponding to the same period, showed low expressions in both seasons although the hypoxic level was obtained with periodic frequency in the rainy season.

Besides, it was reported a red tide composed by the toxic dinoflagellate *Heterocapsa circularisquama* in June/2009, occurring in a shallow area close to sewage effluents, associated to a small fish death event (Moreira *et al.* 2014).

The previous analyses generated classifications of trophic state Moderate-Low for rainy season, and Low for dry season according to the matrix proposed (Figure 2). However, the impact was evaluated acceptable according to the matrix proposed by Pérez (2013), taking into account the low probability of occurrence and the severity as slight.

From the proposed tool for analyzing the eutrophication risk, Cienfuegos bay was classified with risk, although the pressure indicator was not high and the trophic state was not eutrophic. This result justified the necessity of an effective environmental management plan, related to water eutrophication from the preventive point of view.

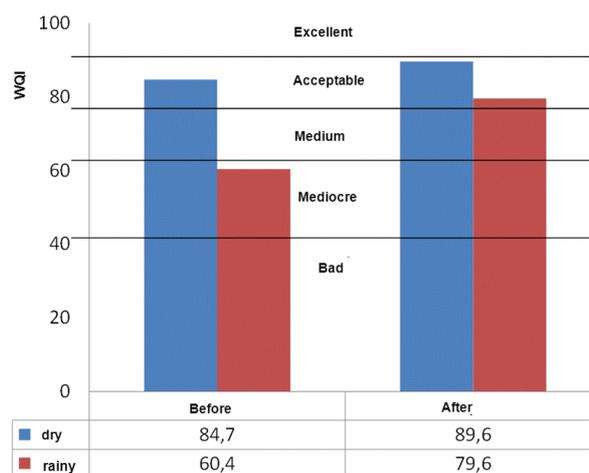
The results from the diagnosis and analysis of the main nutrient contributions were shared with the stakeholders through a participative workshop. The analysis of the nutrient loads showed the highest contribution from the rivers (75%) and some of them (Caunao, Inglés, Damují) were identified as the main nutrient sources. It was also identified the direct drainage contribution from Cienfuegos city as second nutrient source (21 %).

Stage III (To implement): The priority and resources analysis with the stakeholders allowed designing preventive actions to avoid the further detriment of the water quality from trophic state.

This stage included the implementation of the actions defined in the general action plan for this environmental management.

Stage IV (To control and evaluate): After one year of implementing this methodology, the value of indicator related to environmental action execution increased from 68% to 77%. This increase was in correspondence with the increment of indicator related to environmental strategies of polluting entities from 52% to 83%.

The nutrient load incorporated from rivers decreased 310 ton/year, generating a positive change on the water quality according to the result of WQI. This index showed improvement of water quality based on a change from mediocre to acceptable quality in the rainy season, when is greater the water quality detriment (Figure 6). This water quality improvement generated a change of nutrient load indicator evaluation from regular to very good.



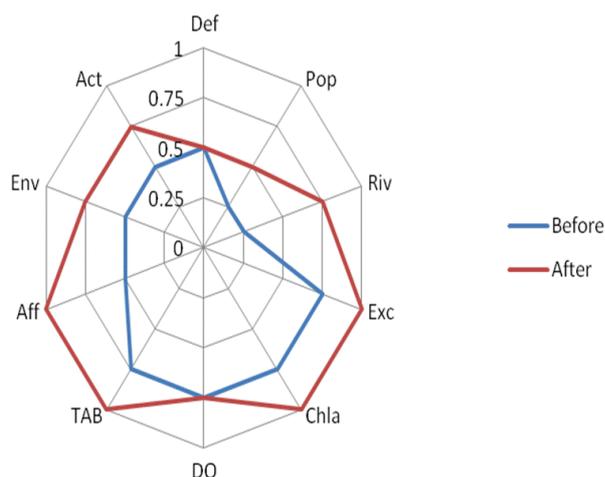
**Figure 6.** Results of Water Quality Index (WQI) before and after implementing the proposed methodology

This nutrient load reduction also generated a decrease of pressure indicator value from 0.9 to  $0.85 \times 10^{-8}$  ton/m<sup>3</sup>d. As this last value is below the

proposed threshold, the pressure was not considered high. Although the deforestation indicator value showed a slight decrease of 0.52%, it was still evaluated as regular.

The state indicators based on chlorophyll *a* and bottom dissolved oxygen expressions were classified as low for both seasons (rainy and dry). We did not identify any toxic algae blooms. Neither did we find any associated harms to aquatic organisms.

The comparative analysis of the indicator results before and one year after implementing the methodology showed a favorable change in 80% of the indicators and the other did not decrease (Figure 7). Besides, the results of non-parametric test (Wilcoxon) showed significant difference among the indicator's results ( $p < 0.05$ ).



**Figure 7.** Indicator results before and after implementing the proposed methodology.

*Testing the feasibility of the proposed methodology application in Cienfuegos bay:* One year after implementing this methodology, the group satisfaction index value was 0.69.

## Discussion

In this case, the nitrogen and phosphorus were considered because this system shows seasonal and spatial variability on the limiting nutrient (Seisdedo *et al.* 2011), as proposed some eutrophication management strategies in estuarine systems (Conley *et al.* 2009, Savage *et al.* 2010).

The results of priority analysis allowed carrying out different campaigns by the work groups for identifying problems in the basins with more nutrient contributions and for proposing the required actions.

The slight changes obtained from the indicator results related to deforestation and population with sewer treatment system showed the need to increase the investments in both aspects. Despite of the short period of testing this methodology, we could appreciate the notable investments required in order to achieve significant changes in both indicators, and the search of financial funds through international projects was also considered.

It was recognized by the Management Authority as one important achievement of application of this methodology, also the increase of communication and educational actions in the nearby communities. However, it is needed to continue working on the community engagement in all the stages of this methodology.

On the other hand, it was considered the need of evaluating the effectiveness of the environmental actions of the main polluting entities with the implementation of the new regulation of CITMA (2014) for controlling the emission of polluting loads.

The group satisfaction index value showed the acceptance of this methodological proposal and its utility for the improvement of water quality from trophic state.

## Conclusions

The conceptual model and the methodology of this environmental management offered a way to improve the water quality from trophic state in Cuban estuarine systems based on the couple of the eutrophication risk analysis and systemic and causal approaches. Also, the methodological proposal allowed to guide appropriately the actions of environmental management and to evaluate its effectiveness in Cienfuegos bay.

The proposed tools for the diagnosis and evaluation stages allowed identifying the necessity of managing the eutrophication in Cienfuegos bay from preventive point of view and testing its feasibility as a tool for managing this environmental problem in estuarine systems with similar characteristics.

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