ENVIRONMENTAL MONITORING AND MANAGEMENT DURING THE CONSTRUCTION DREDGING FOR THE FIRST STAGE OF THE NEW PORT OF VERACRUZ, MEXICO

J. I. Ramírez-Macías[1], F. Liaño-Carrera[2], T. Camarena-Luhrs[3], A. E. Gómez-Barrero[4] and D. Salas-Monreal[5]

ABSTRACT

The Veracruz Port Authority (APIVER) began, in 2015, the New Port of Veracruz construction, which represents the most ambitious port project in the last hundred years in Mexico. This project will increase by 400% port´s current capacity, positioning it as one of the most important ports in Latin America. The port of Veracruz expansion has had to overcome multiple challenges among which those of environmental nature stand out. The new port of Veracruz is located next to the marine protected area denominated "Veracruz Reef System" (VRS) and most of the environmental actions conducted during the port construction are directed to protect the coral reefs in the VRS. The first stage of the New Port of Veracruz requires the dredging of almost twelve million cubic meters and represents the activity with the greatest potential to affect the marine protected area. In 2014, APIVER initiated a monitoring program with the aim to study sediments dynamics on the construction site and the nearest VRS coral reefs (Gallega, Galleguilla y Blanquilla). Sediment dynamics knowledge was the baseline for the creation of a real-time monitoring system developed in collaboration between APIVER and VRS authorities. The monitoring system was published on an open access web page, where the maps generated in real time showed all the information collected on current patterns and suspended particles concentration together with other variables of interest. Real-time monitoring was complemented by drones-assisted supervision, light intensity and sedimentation rates monitoring and ecological condition assessment of the coral reefs studied. During the execution of dredging operations, the monitoring system was a useful environmental management and assessment tool. This article details the monitoring system characteristics and highlights its relevance for the new port of Veracruz environmental performance assessment.

Keywords: Veracruz Reef System, coral reefs, sediment dynamics, real-time monitoring, environmental impact.

INTRODUCTION

New Port of Veracruz project.

At the end of the nineties, the need to expand the installed capacity of the port of Veracruz to maintain its competitiveness in the market was evident. Since that date, the Port of Veracruz Authority (APIVER) began to design a port expansion project which could satisfy not only technical and economic demands but also could prevent significant environmental impacts. The resulting port expansion project is known as the New Port of Veracruz

[1]Project Manager, New Port of Veracruz Environmental Management System, Argo Consultores Ambientales S.A. de C.V, Zona Portuaria, Veracruz, Ver., C.P. 91891, T: (52) 229 929 0123, E-mail: isaac.ramirez@argoconsultores.com.

[2]Engineering Manager, Administración Portuaria Integral de Veracruz S.A. de C.V., Avenida Marina Mercante 210, Colonia Centro, Veracruz, Ver., México, C.P. 91700, T: (52) 229 923 2170, E-mail: flcarrera@puertodeveracruz.com.mx

[3]Protected Area Director, Parque Nacional Sistema Arrecifal Veracruzano, Comisión de Áreas Naturales Protegidas, Juan de Grijalva 78, Fracc. Reforma, Veracruz, Ver., C. P. 91919, México, T: (52) 229 937 4557, E-mail: tcamarena@conanp.gob.mx.

[4] Managing Director, Argo Consultores Ambientales S.A de C.V, 6º Retorno de la Avenida Osa Menor 43-3, Rerserva Territorial Atlixcayotl, San Andrés Cholula, Puebla, C. P. 72810, T: (52) 222 431 4472, E-mail: agomezbarrero@argoconsultores.net.

[5] Full-time researcher, Instituto de Ciencias Marinas y Pesquerías, Universidad Veracruzana, Hidalgo 617, Col. Río Jamapa, Boca del Río, Veracruz, C.P. 94290, México, T: (52) 229 956 7227. E-mail: davsalas@uv.mx.

(NPV), which represents one of the biggest infrastructure projects in Mexico in recent times and the most important port construction in the last one hundred years (Ramírez-Macías et al., 2017).

The NPV will be created on reclaimed land considering the construction procedures of the highest standards worldwide, quadrupling the capacity of commercial load from 23 to 95 million tons and will become the most important port in Mexico.

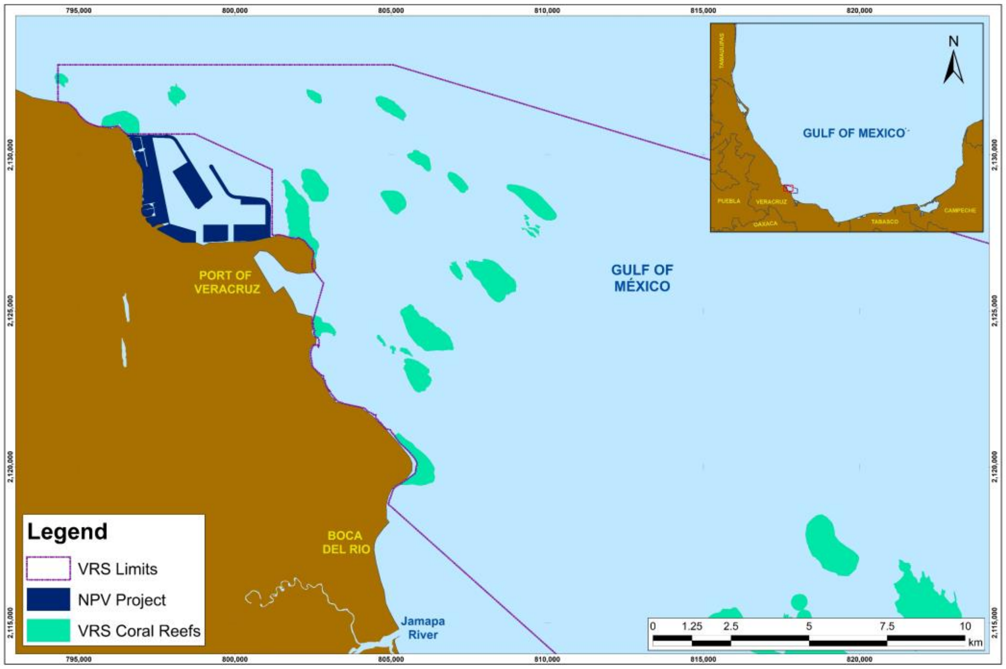

Figure 1. New Port of Veracruz location in the Gulf of Mexico.

The New Port of Veracruz is being constructed in the Vergara Bay, located northern to the current port of Veracruz. Veracruz is in the southern part of the Gulf of Mexico (Figure 1) and it is surrounded by a marine protected area denominated the Veracruz Reef System (VRS). The coral reefs of VRS represent the main environmental concern of the NPV and, during the construction phase, dredging is the most threatening activity for them. These potential impacts of dredging were first considered in the environmental impact study and in the group of mitigation measures proposed by APIVER. Later, the environmental impact authorization also constrained the dredging works. In recognition of the relevance that the development of the dredging would have for the project and the implicit environmental impact potential, APIVER began to study sediment dynamics by building a sophisticated monitoring system which preliminary results are presented in this work.

New Port of Veracruz first stage dredging project.

The first stage of the New Port of Veracruz consists of a breakwater of 4.2 kilometers (km) in length that houses a port area with terminals specialized in fluids, agricultural and mineral bulk, general cargo and containers. All terminals will be built on an area of around 200 hectares (ha) of reclaimed land with dredged material.

The dredging of the first stage of the NPV has the purpose of also enabling the navigation channel and the turning basin with 15 meters (m) of depth. A total of 133 ha will be dredged between the slope and the depth dredging for the conformation of the dock and access channel. An estimated volume of 12.8 million cubic meters (m^3) will be dredged and used for land reclamation. The following figure illustrates the dredging project (Figure 2).

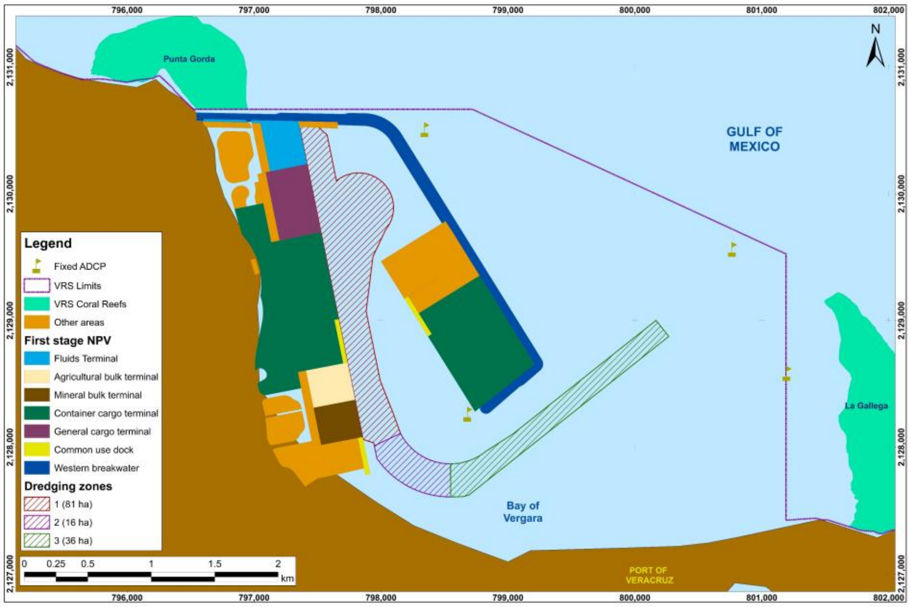

Figure 2. New Port of Veracruz first stage and related dredging and filling zones.

A fundamental part in the success, in environmental terms, of a dredging project depends on the selection of the most adequate equipment that allows the most efficient development of the works and therefore a reduction in the magnitude of associated environmental impacts. The first stage of the New Port of Veracruz dredging project is to built using a cutter suction dredge and a trailing suction hopper dredge, both of great power and selected taking into account both the technical aspects of the project and the environmental needs. The main characteristics of the dredges used are presented in Table 1.

Table 1. Dredging Equipment Specifications.

	
Name: Willem Van Oranje Type: Trailing suction hopper dredge Length overall: 137 m Length between perpendiculars: 125 m Beam: 28 m Moulded depth: 13.5 m Hopper capacity: 12,000 m^3	Name: Marco Polo Type: Cutter suction dredge Length: 116.5 m Breadth: 19 m Draught: 4.85 m Dredging depth: 32 m Suction pipe diameter: 900 mm

Baseline monitoring.

Given the magnitude and importance of the dredging for the NPV, APIVER started, prior to the beginning of the construction phase, with the monitoring and study of sediment dynamics in Vergara Bay and the closest VRS reef formations. This study had the central objective of knowing current patterns and the concentration of particles in the water column. Vessel mounted and fixed Acoustic Doppler Profilers (ADCP) were used to perform the sediment dynamics study (Liaño-Carrera et al., 2017). These instruments have been widely used to monitor sediments (Riverón-Enzastiga et al., 2016, Dwinovantyo et. al, 2017; Liaño-Carrera et. al, 2017).

The use of the vessel mounted profiler allowed the generation of a detailed current pattern and sediments concentration maps in Vergara Bay and projects direct influence area on VRS (Gallega, Galleguilla and Blanquilla). These maps have been made weekly since 2014 and have registered the dynamics of sediments under the three characteristic seasons in the VRS and understanding how factors such as the contributions of the rivers and discharges of wastewater treatment plant influence (Figure 3). Sediment dynamics at Bay level was also characterized with a permanent monitoring using a fixed profiler which recorded current´s direction and velocity and concentration of particles every ten minutes from the start of monitoring in 2014. Data from fixed profiler were also transmitted in real time and were available for consultation through a web page and made possible the creation of the actual monitoring system in real time using four profilers.

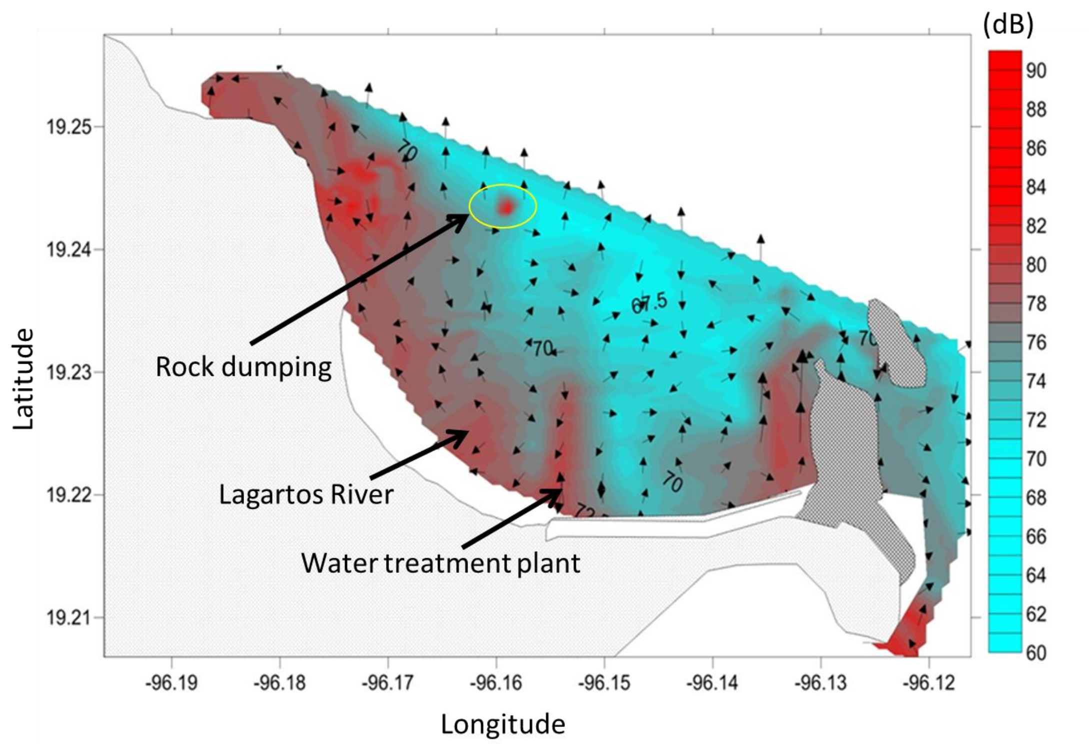

Figure 3. Example of sediment dynamics map during the baseline monitoring period. Adapted from Ramírez-Macías et al. (2017).

This monitoring has also captured the effects of western breakwater construction, as illustrated in Figure 3, laying the foundations to understand the contribution of rock dumping in local sediment dynamics and thus assessing the associated level of environmental impact (Ramírez-Macías et al., 2017).

Turbidity and sediments studies normally use NTU (Nephelometric Turbidity Units) or mg L^{-1} as units to report particles concentration in the water column. However, when using ADCP as particles monitoring equipment, sediments concentration is indirectly inferred from absolute acoustic intensity expressed as dB. In all the monitoring process, turbidity and suspended sediments have been measured to relate to acoustic intensity, but a poor relation was found despite the evident ADCP ability to correctly characterize sediment concentration. The decision after this situation was to continue with the ADCP monitoring and elucidate later on the relationship between decibels, turbidity and suspended sediments concentration. It was possible to demonstrate this relationship because particles concentrations were distinguished and because the data gathered from satellite transmission technology was well stablished using ADCP´s.

DREDGING ENVIRONMENTAL MONITORING SYSTEM

Dredging operations have, many cases, contributed to the loss or detriment of coral reef habitats, either directly due to removal or burial of reefs, or indirectly as a consequence of elevated turbidity and sedimentation (Erftemeijer et al., 2012). APIVER developed a monitoring system focused on the three main effects of physical proximate stressors associated with turbidity generating events: elevated suspended-sediments, changes in light quality and quantity and sediment covering (Jones et al., 2016). Dredging environmental monitoring components are illustrated in Figure 4.

Figure 4. New Port of Veracruz dredging monitoring.

Regarding sediments dynamics, NPV dredging monitoring includes a web-based, real-time monitoring and a detailed current and sediments pattern monitoring using a vessel mounted ADCP, which has not been interrupted since 2014. Environmental dredging monitoring also integrates direct measurement of light intensity, temperature and sedimentation rates along with general ecological condition evaluation in nearby VRS coral reefs. Finally, a satellite and drone images derived follow-up and assessment has been conducted to complement dredging environmental performance assessment. Figure 5 show how monitoring components are distributed in the study area.

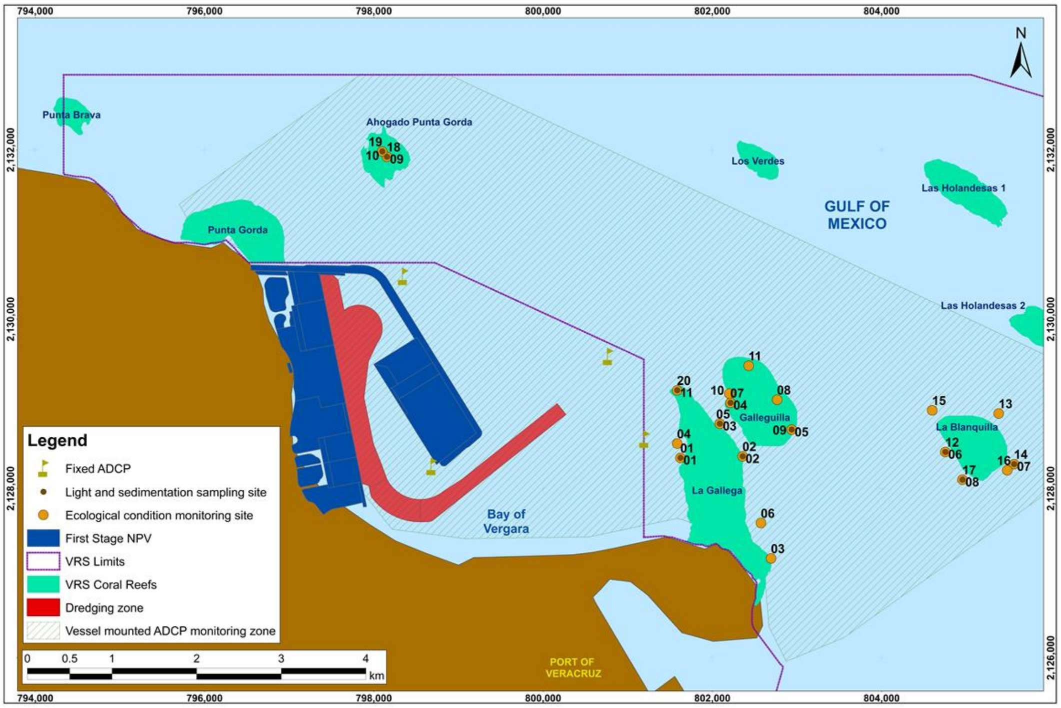

Figure 5. Dredging environmental monitoring extent and sampling sites location.

Real-time monitoring system.

A real-time monitoring system was built using satellite transmitted data from a set of four ADCP´s installed in oceanographic buoys. A special computer software was programed to interpolate data coming from fixed profilers and to generate maps every ten minutes (see example maps in Figure 6). These maps also contain the same information than baseline vessel mounted generated maps: current patterns (direction and velocity) and sediment concentrations expressed as decibels. Along with the maps, meteorological information is also available, specifically wind speed and direction because the environmental impact permit establishes a wind velocity threshold (50 km h^{-1}) to dredging operations.

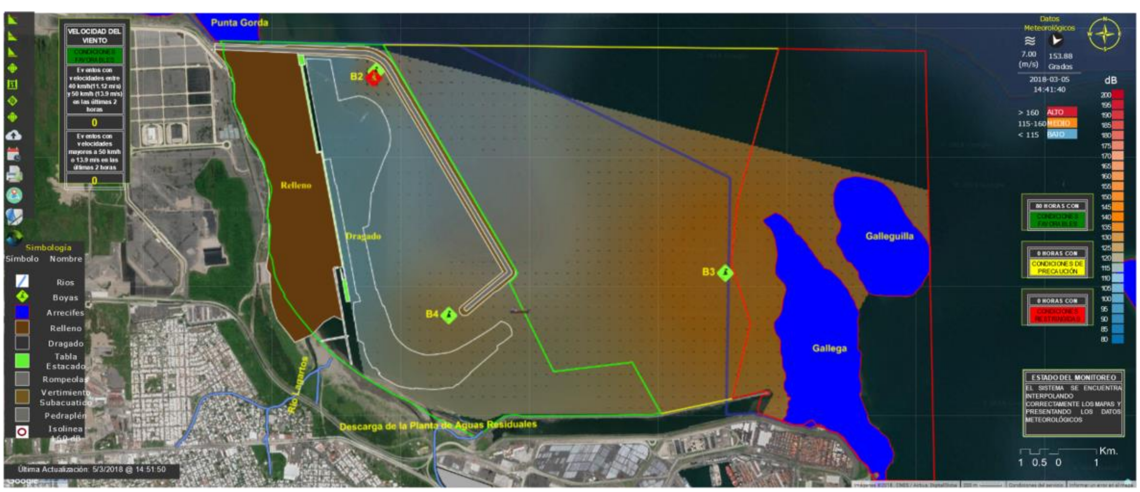

Figure 6. Map from real-time monitoring website.

All the maps are shown in real-time in an open access website (http://produc.eastus.cloudapp.azure.com:8082/login) where users could register and login. There are two types of users with different faculties: stakeholders users and public users. Stakeholders users were able to download historic maps and data, manage different layers on the map, generate and download graphics and tabulated data from every fixed ADCP. Public users have exclusive access to the visualization of the most recent map generated and to the last wind velocity report.

Another important information that real-time maps provide is sediments concentration and distribution in three different management zones. Sediments related to dredging activities must remain on the green and yellow zones and if they exceeded that limit emergency actions should be executed. However, when high sediment concentrations (those above 160 dB) are registered in the yellow zone, different management actions are executed, such as; dredging pauses, changing the dredging area or even a complete stop of the process, if it was necessary.

The real-time monitoring system was properly tested prior to the beginning of the dredging process and it is being fully utilized during all the dredging operations to manage environmental aspects and compliance assurance. VRS authorities have full access to the monitoring information, as well as the dredging company and other related environmental agencies. Some other important aspects regarding environmental management of dredging are detailed further in this work.

Vessel mounted ADCP dredging monitoring.

Vessel mounted ADCP monitoring has continued since 2014 because it has proven that it characterizes sediment dynamics with high accuracy. Real-time maps are interpolated with just four points, while mobile ADCP maps are generated from thousands of interpolated points, providing more detailed information about Vergara Bay sediment dynamics. An example of the kind of maps produced in the dredging period is presented in Figure 7, which reflects sediment dynamics in October 27, 2017.

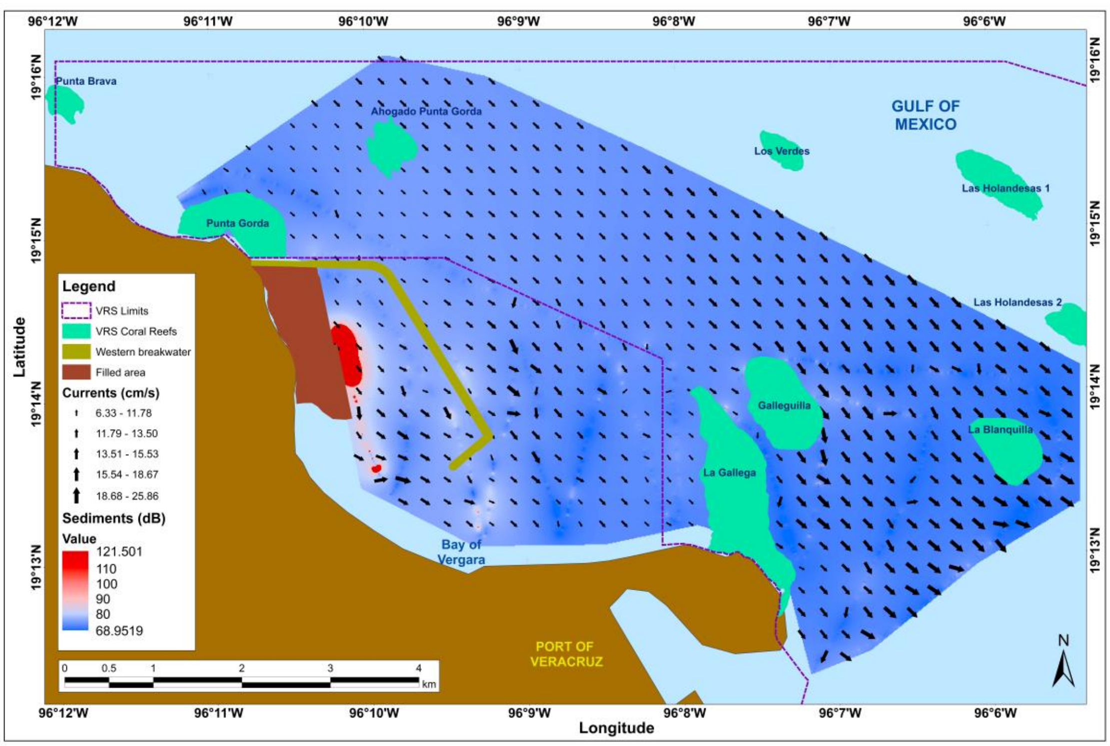

Figure 7. Map showing currents pattern and inferred sediment concentration from vessel mounted ADCP data. (October 27, 2017).

A cutter suction dredge was being used in October 27, 2017 and high sediment concentration values were located along the filling site. Sediments remained on the authorized area and higher values were far enough from fixed ADCP and were not recorded in real-time maps. However, mobile ADCP maps captured all the variation in Vergara bay and the results are congruent with information coming from other sources of information such as drone supervision. Figure 8 shows how sediments entered in the bay along the filling zone and how they remained there.

Figure 8. Example of drone capture from dredging operation during environmental supervision.

Drone assisted supervision and monitoring.

Unmanned aerial vehicles (UAV) or drones have been crucial for dredging monitoring and supervision. Drones in the NPV have been used to supervise dredging operations performance. Nowadays UAV´s technology allows their use in professional supervision and monitoring. Daily, if weather conditions are adequate during dredging execution, all operations are filmed and photographed with a commercial quadcopter drone to supervise their environmental compliance and to complement sediments dynamics monitoring. Drone captured images are a powerful tool in the management and communication of all the environmental aspects of dredging.

Figure 9. Example of drone capture from dredging operations during environmental supervision.

Light intensity and sedimentation rates monitoring.

Other important aspects in the coral reef zones are being studied as part of the dredging monitoring. Light intensity and temperature are monitored continuously with sensors, which record these parameters every fifteen minutes. Temperature and light are two limiting variables to coral reefs and light availability can decrease by dredging sediments input (Erftemeijer et al., 2012, Jones et al., 2016). The aim of these monitoring is to generate time series of this parameters and detect any change in light intensity which could be related to dredging operations. Although all monitoring components can support an effective environmental performance of dredging it has to be demonstrated that coral reefs were not affected either.

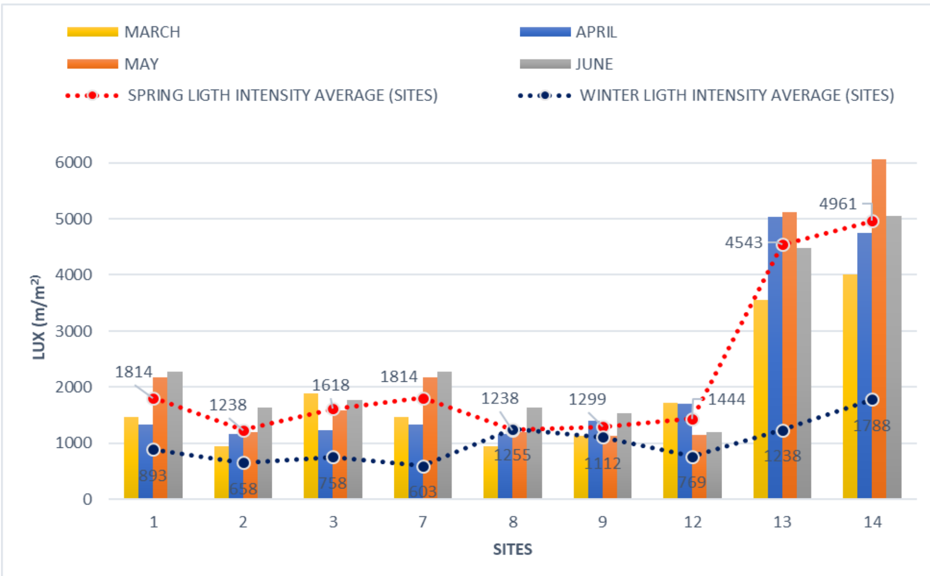

Figure 10. Example of light intensity monitoring from March to June in 2017. Colors bars represent monthly maximum values of light intensity in luxes, registered in the period. Red dotes line indicates period average and blue line indicates 2016-2017 winter light intensity average.

Light intensity monitoring and the related data must be deeply analyzed and refined to elucidate any relationship with dredging. However, it will be possible because monitoring of light intensity has been conducted before and during dredging development.

Sedimentation rates are determined along with light and temperature monitoring with sediment traps which are collected monthly. Sediments could cover coral reefs and cause severe damage on them and this condition would be catastrophic during dredging execution. VRS naturally presents very high sedimentation rates compared with other coral reefs ecosystems. During the period from March to June in 2017, before dredging, sedimentation rates higher than 3,500 g m^{-2} in one day were recorded.

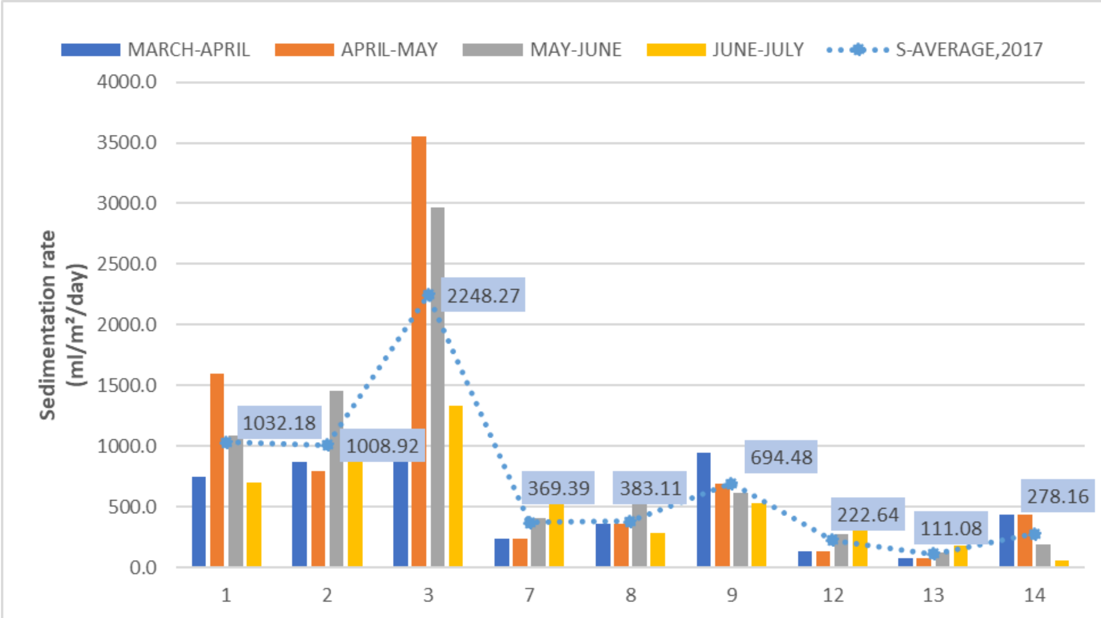

Figure 11. Example of sedimentation rates monitoring from March to June in 2017. Colors in bars represent monthly sedimentation rate maximum value in g m^{-2} per day registered in the period (yellow bar corresponds to March). Blue dotted line indicates spring averages.

Coral reefs condition assessment.

Evaluating overall coral reefs condition was also indispensable to determine if dredging affected or not the nearest VRS coral reefs. Ecological condition was evaluated in twenty sites in the nearest VRS coral reefs (Figure 2). In these sites, coral cover and syndrome condition was determined along with physicochemical water quality parameters. Preliminary results are not conclusive, but they already confirm a deterioration tendency of the VRS coral reefs, which has been registered before in the setting of Veracruz Port expansion project. The coral reef closest to the port expansion project denominated "La Gallega" shows the lowest coralline cover value: around 5% and coral cover increases with the distance to coast.

Coral reefs, like many other marine ecosystems, are increasingly subjected to elevated levels of eutrophication, sedimentation and turbidity, factors proposed to compromise disease resistance of corals and/or increase pathogen virulence (Pollock et al., 2014). Thus, syndrome prevalence in corals is a good indicator of anthropogenic pressure, but there is not an historic record for VRS as in the case of coral cover, that is why it must be studied in depth and further monitoring and analysis must be done. A graphic with some preliminary results regarding coral cover and syndrome prevalence is shown in Figure 12.

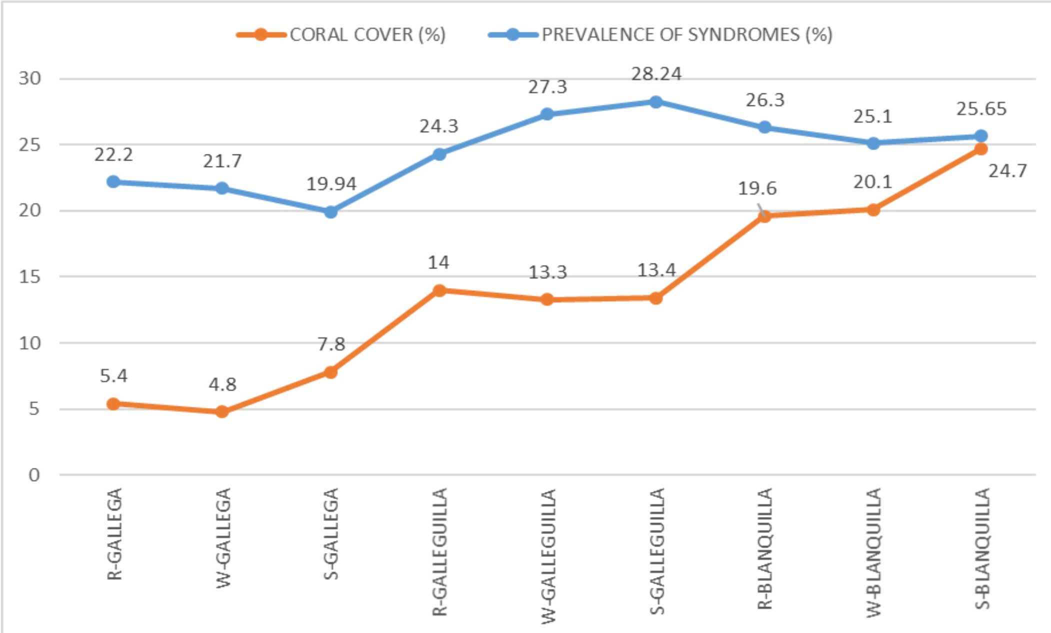

Figure 12. Percentage of coral cover and syndrome prevalence for VRS study in three different sampling seasons during 2016 and 2017 (R: rainy season, W: winter, S: spring).

Dredging adaptive management.

In major dredging projects where the final result is uncertain or is accompanied by low confidence in the prediction of their effects, a sequence of more intense and targeted monitoring, impact assessment and management actions might be implemented on a continuous or regular basis for the duration of (and after) the project, in order to keep project expectations and implementation requirements more manageable (CEDA, 2015). This sequence of activities is jointly understood as 'Adaptive Management' (CEDA, 2015).

An adaptive management approach was applied to NVP dredging monitoring from planning phase. The monitoring design was the outcome of cooperative work among different stakeholders: marine protected area authorities, academic specialists, port authorities and others. NPV dredging monitoring has not only been useful in terms of dredging environmental follow-up and evaluation. Monitoring has also been the main environmental management tool, providing stakeholders timely and reliable information to execute the planned management actions or adopting new actions that they believe necessary according to the evolution of the dredging works.

Adaptive management requires to continuously review monitoring results to assess if the environmental goals are achieved and adapt monitoring, management actions or objectives if it were necessary. Dredging monitoring system has fully operated since March 2017, few months prior to the beginning of dredging. All stakeholders have played an active role in NPV dredging monitoring implementation and reviewing all the results. To date few changes have been made to monitoring system and the environmental management plan.

CONCLUSIONS

New Port of Veracruz is one of the largest port construction projects in recent times. NPV fragile environment condition required the design and implementation of an outstanding monitoring plan, which allowed dredging without significant affectations to the VRS coral reefs. Using the best available technology and covering a wide range of variables, APIVER has monitored dredging effects on VRS coral reefs and has also executed effective management actions.

The NPV dredging monitoring and the related management are good examples of the application of adaptive management approach to major infrastructure projects. Preliminary results of monitoring are positive, but NPV is a long-term project and the monitoring results must demonstrate in the future that dredging was developed in accordance to the objectives defined.

CITATION

Ramírez-Macías, J. I., Liaño-Carrera F., Camarena-Luhrs T., Gómez-Barrero A. E. and Salas-Monreal D. "ENVIRONMENTAL MONITORING AND MANAGEMENT DURING THE CONSTRUCTION DREDGING FOR THE FIRST STAGE OF NEW PORT OF VERACRUZ, MEXICO", *Proceedings of the Western Dredging Association Dredging Summit & Expo '18, Norfolk, VA*, USA, June 25-28, 2018

REFERENCES

Central Dredging Association. (2015). *Integrating adaptive environmental management into dredging projects*. Radex Innovation Centre, Rotterdamseweg HD Delft, The Netherlands.

Erftemeijer, P. L. A., Riegl, B., Hoeksema, B. W. and Todd, P. A. (2012). *Environmental impacts of dredging and other sediment disturbances on corals: A review*. Marine pollution bulletin. 64(9): 1737–1765.

Jones, R., Bessell-Browne, P., Fisher, R., Klonowski, W. and Slivkoff, M. (2016). *Assessing the impacts of sediments from dredging on corals*. Marine pollution bulletin, 102(1): 9-29.

Liaño-Carrera, F., Ramírez-Macías, J.I., Salas-Monreal, D., Riverón-Enzástiga, M. L., Rangel-Ávalos, M. A. and Roldán-Ubando, A. A. (2017). *Sediment Transport Monitoring in the Port of Veracruz Expansion Project*. World Academy of Science, Engineering and Technology, International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering. 2017 (11): 204-209.

Pollock, F. J., Lamb, J. B., Field, S. N., Heron, S. F., Schaffelke, B., Shedrawi, G., andWillis, B. L. (2014). Sediment and turbidity associated with offshore dredging increase coral disease prevalence on nearby reefs. *PLOS one*, *9*(7): e102498.

Ramírez-Macías, J. I., Liaño-Carrera, F. and Baños-Illana J.E. (2017). *Follow-up monitoring and adaptive management in EIA process: a case study in the new port of Veracruz construction phase*. 37th Annual Conference of the International Association for Impact Assessment. Canada. 2017.

Riverón-Enzastiga, M. L., Carbajal, N., & Salas-Monreal, D. (2016). *Tropical coral reef system hydrodynamics in the western Gulf of Mexico*. Scientia Marina, 80(2): 237-246.

ACKNOWLEDGEMENTS

This work was financed by Administración Portuaria Integral de Veracruz S.A. de C.V. (APIVER) in the context of the New Port of Veracruz environmental impact assessment follow-up monitoring. Authors would like to thank all monitoring work team: Andrea Roldán-Ubando, Marcos Rangel-Ávalos, Paul Ávila, Erik Paredes-Juárez, Marco Juárez-Martínez, Ricardo Moreno-García and Job López-Acevedo.