Perea-Ardila, M. A., F. Oviedo-Barrero, S. Monsalve-Rocha, M.A. Ocampo-Rojas, 2021 Identification of synergies and conflicts in coastal and marine uses in Colombian Pacific: a spatial multi-criteria analysis. *Revista Costas, vol. esp.,* 2: 165-182. doi: 10.26359/costas.e0821

Institucional Management Report / Relatórios de Gestão Institucionais / Informe de Gestión Institucionales

Identificación de Sinergias y Conflictos en Usos Costeros y Marinos en el Pacífico Colombiano: un Análisis Espacial Multicriterio

Identification of Synergies and Conflicts in Coastal and Marine uses in Colombian Pacific: a Spatial Multi-Criteria Analysis

Mauricio Alejandro Perea-Ardila[1], Fernando Oviedo-Barrero[1], Sabrina Monsalve-Rocha[1], María AlejandraOcampo-Rojas[2]

e-mail: mapereaa@ut.edu.co

[1] Área de Manejo Integrado de Zona Costera, Centro de Investigaciones Oceanográficas e Hidrográficas del Pacífico - CCCP - Dirección General Marítima. Tumaco, Colombia.

[2] Área de Litorales - Subdirección de Desarrollo Marítimo - Dirección General Marítima. Bogotá D.C, Colombia.

Submitted: October 2020

Accepted: February 2021

Associate Editor: Alejandro Iglesias-Campos, Michele Quesada-Silva y Martina Camiolo

Keywords: Marine Spatial Planning, Colombia, spatial analysis, multi-criteria, Planning, GIS Tools.

Abstract

The increasing demands for physical space towards diverse maritime activities call for coherent planning and scientific knowledge to support the management of the marine the environment. Using secondary multi-scale geographic information gathered from national institutions, expert judgment and a multi-criteria analysis integrated with GIS tools, we aimed to identify potential synergies and conflicts between human activities occurring in the jurisdiction of the master harbor of Buenaventura in the Valle del Cauca department (CP01) in the Colombian Pacific coast. We identified 105 overlaps in which 5.04% were categorized with high CNI (Conflict Normalized Index), while 13 interactions were evaluated with the highest conflict value, representing 14 sectors/groups. Additionally, 12.97% of the overlaps were categorized with a medium number of overlaps (4-6 overlays use), specifically distributed inside the Buenaventura Bay. Conservation uses (Protected Areas – SINAP in Colombia) was consistent within all 13 incompatibilities and conflicts distribution along the study area was not homogenous. The methodological approach used in this study can be used to identify conflicts and synergies in human uses and activities in the marine and coastal environment through the implementation of a methodology adapted to the context of the area. It presents a technical contribution to future processes of Marine/Maritime Spatial Planning and the Integrated Management of the Coastal Zone of Colombia.

Resumen

La creciente demanda de espacio físico hacia diversas actividades marítimas exige una planificación coherente y un conocimiento científico para apoyar la gestión del medio marino. Utilizando información geográfica multiescala recopilada de todos los actores institucionales al nivel nacional, juicio de expertos y análisis multicriterio integrado con herramientas SIG, nuestro objetivo fue identificar posibles sinergias y conflictos entre las actividades humanas que ocurren en la jurisdicción de la Capitanía de Puerto de Buenaventura (CP01) de la Dirección General Marítima – Dimar, en el departamento del Valle del Cauca y Chocó en la costa del Pacífica colombiana. Como resultado, se identificaron 105 cruces de información, donde el 5,04% correspondió a un Ííndice de Conflicto Normalizado (ICN) alto, siendo 13 interacciones las de mayor valor de conflicto , representado en 14 sectores/grupos. Asimismo, el 12,97% presentó un numero de conflicto medio (entre 4 y 6 superposiciones entre usos) al ingreso de la Bahía de Buenaventura. El Sistema Colombiano de Áreas Protegidas (SINAP en Colombia) fue consistente dentro de las 13 incompatibilidades registradas y la distribución de los conflictos a lo largo del área de estudio no fue homogéneo. El enfoque metodológico empleado en este estudio puede ser utilizado para la identificación de conflictos y sinergias en usos y actividades humanas en el medio marino y costero mediante la implementación de una metodología adaptada al contexto de la zona. Se presenta un aporte técnico a futuros procesos de Planificación Espacial Marina/Marítima y al Manejo Integrado de la Zona Costera de Colombia.
Palabras clave: Planificación Espacial Marina, Colombia, Análisis espacial, Multicriterio, planificación, herramientas SIG.

1. Introduction

Marine and coastal resources provide an array of goods and services, but consequently, experience a continuously rising demand in response to a growing global population and the increase of anthropogenic activities (Mcgrath, 2004; Ehler & Douvere, 2009; Tuda *et al.,* 2014). Likewise, the temporal and spatial scale of these activities varies throughout different economic sectors, each with specific characteristics, generating incompatibilities between users and uses (Burger & Leonard, 2010). Moreover, regulating legislations are developed independently by each pertinent authority in each sector without prior inter-institutional coordination, resulting in a variety of regulations in the marine and coastal zone lacking prior integral planning (Mcgrath, 2004).

Furthermore, human activities that use ocean resources need meticulous and integrated spatial-temporal planning to avoid sector-specific incompatibilities between uses and to prevent decreasing marine and coastal ecosystem capacities (Ehler & Douvere, 2009; Moore *et al.,* 2017). As a response, countries worldwide have introduced the use of Marine Spatial Planning (MSP) intending to allocate specific areas to each activity with an equitable distribution to address emerging conflicts in marine and coastal environments ensuring a socio-cultural, economic, and ecological balance between interests (Ehler & Douvere, 2009). To do so, identifying and describing the spatiotemporal distribution of all existing human activities, regulations, and existing or potential conflicts is essential to solve spatial multiple-use problems by applying an MSP methodology adapted to the characteristics of the study area (Gourmelon *et al.,* 2014; Prestrelo & Vianna, 2016). This, combined with Geographic Information Systems (GIS) tools and multi-criteria techniques (Multi-Criteria Decision Analysis - MCDA) with expert judgment have the potential to significantly improve information and data management efforts, deeming these as important instruments in marine management and decision making (Rojas *et al.,* 2010; Stamoulis & Delevaux, 2015; Gimpel *et al.,* 2018). Several countries have started to implement MSP as an approach to potentially reduce conflicts and foster sustainable use of marine resources. The MSP popularity has increased in the Belgian part of the North Sea (Douvere *et al.,* 2007), Canada (Ban *et al.,* 2013), Australia's Great Barrier (Day, 2015), Scotland (Smith & Jentoft, 2017) and the island of Crete in Greece (Tsilimigkas & Rempis, 2018). The MSP will likely keep expanding in the coming decade because has gained momentum globally as new countries start to discuss the development of ocean planning initiatives, marine spatial plans are currently under development in about 70 countries, but only 25 countries have marine spatial plans that are already implemented or at least government-approved (Frazão-Santos *et al.,* 2020).

Nevertheless, most of these examples are driven and framed as part of European policy (Douvere *et al.,* 2007) or a renewed commitment to achieving marine planning (Ban *et al.,* 2013). In the same way, most of the MSP projects have undergone prior collation and structuring of ecological, physical, social, and economic data to provide necessary inputs to the MSP methodology itself. However, in the interest of constructing medium to long term marine master plans, developing countries may lack available spatial information regarding marine and coastal uses and activities. Additionally, if data is indeed available, information may be sector biased and difficult to access, making MSP processes slow and in many ways, skewed towards countries with cooperating institutions framed within national oceanic policies as part of a governmental priority. The problem thickens when study areas are complex and portray numerous uses, activities, and a diversity of actors. In this case, information is not only scarce and scattered, but additionally, to genuinely plot the marine and coastal scenario taking place, information needs to be mined regardless of the limited data situation.

With this in mind, using secondary information gathered from stakeholders and using expert judgment through a multi-criteria analysis integrated with GIS tools, we aimed at identify synergies and potential conflicts between human activities occurring in the jurisdiction of the master harbor of Buenaventura in the Valle del Cauca department (CP01) located in the Colombian Pacific coast, from a marine authority perspective as a technical contribution to MSP processes and Integrated Coastal Zona Management (ICZM) in the region (Fabbri ,1998).

This area houses a diverse variety of human activities in the marine and coastal environment that it comprehends and constitutes one of the most important Pacific seaports encompassing various strategic ecosystems and megafauna migratory routes. This, to our present knowledge, is one of the first studies in data deficient regions combining an adapted MSP methodology (Ehler & Douvere, 2009) GIS tools, and MCDA techniques in the Eastern Tropical Pacific region.

2. Materials and methods

Study area

The jurisdiction of the master harbor of CP01 in the Colombian Pacific coast is defined by the General Maritime Directorate (figure 1) from now on "Dimar" (for its acronyms in Spanish Dirección General Marítima), in resolution No. 0825 of 1994 (Dimar 1994) It includes coastal areas, internal waters (0-12 NM), territorial sea (12 NM), contiguous zone (12-24 NM) and the Exclusive Economic Zone (EEZ) (200 NM), comprehending a total of 162.396,18 km^2.This area is characterized as one of the most biologically diverse areas in the world (Rojas *et al.*, 2019). Home to a variety of plants and animal species that inhabit strategic ecosystems key to the marine and coastal ecosystems in the region. Nevertheless, although the area houses diverse cultural knowledge representative of the Colombian Pacific, it is also an area with an array of anthropogenic activities such as fishing, tourism, transport, industries, only to name a few, converging in time and space in CP01.

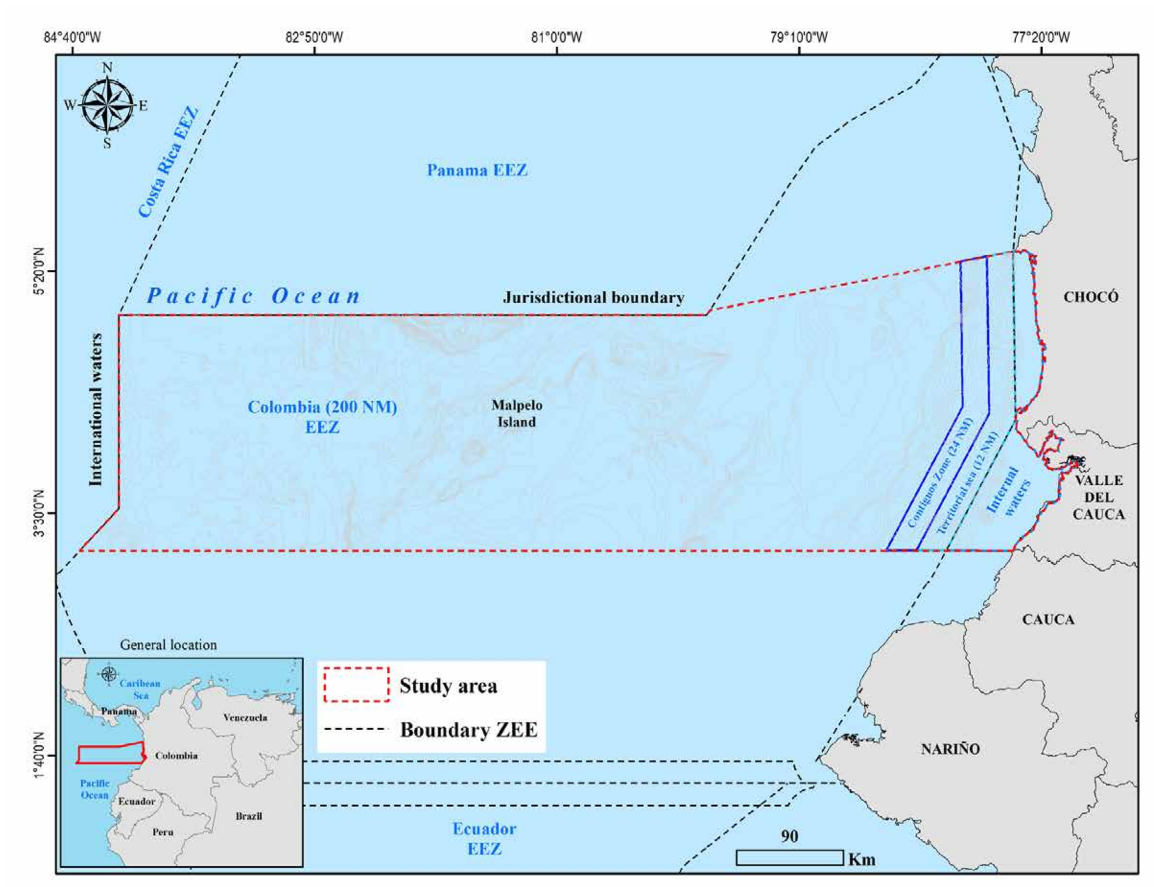

Figure 1. Study area with jurisdictional limits of the CP01 master harbor, Valle del Cauca and Chocó department.
Figura 1. Zona de estudio con límites jurisdiccionales del puerto principal CP01, departamento Valle del Cauca y de Chocó.

Conflict identification

A wide variety of aspects and methodologies have been described regarding territorial planning, nevertheless, only a few can be applied to marine and coastal areas, while others lack concrete indications to approach MSP. This study uses an adapted proposal and methodology for MSP using the Analytic Hierarchy Process - AHP (Saaty, 1990), to identify spatial conflicts and synergies of the uses and activities in the study area as a technical input to the Colombian Pacific, addressing it up to the extent of the digital information available concerning biophysical, maritime, and human activities data (figure 2). Once Spatial information was obtained, data was 1) standardized and shapefiles where sized to the study area, 2) an adapted MCDA through an AHP was performed, in order to calculate 3) conflict index and the number of conflicts that overlap, and then, based on the previous results, 4) generate each graphic output as digital maps.

Conflict is defined by Wilmot & Hocker (2007) as "an expressed struggle between at least two interdependent parties who perceive incompatible goals, scarce resources, and interference from others in achieving their goals". Spatial conflicts arise from direct competition over limited space (two sectors interested in the same location) or one sector negatively impacting on the other (Gee *et al.,* 2018). While, the term Synergy (from the Greek synergos, συνεργός meaning working together, from sun- 'together' + ergon 'work') refers to the combined action in which the effect of the influence of two or more agents when acting together is greater is greater than the sum of the parts taken separately (Latash 2008).

Geographic information compilation and treatment

Geographic information from human activities and uses, as well, as environmental and biological information from the study area was obtained through

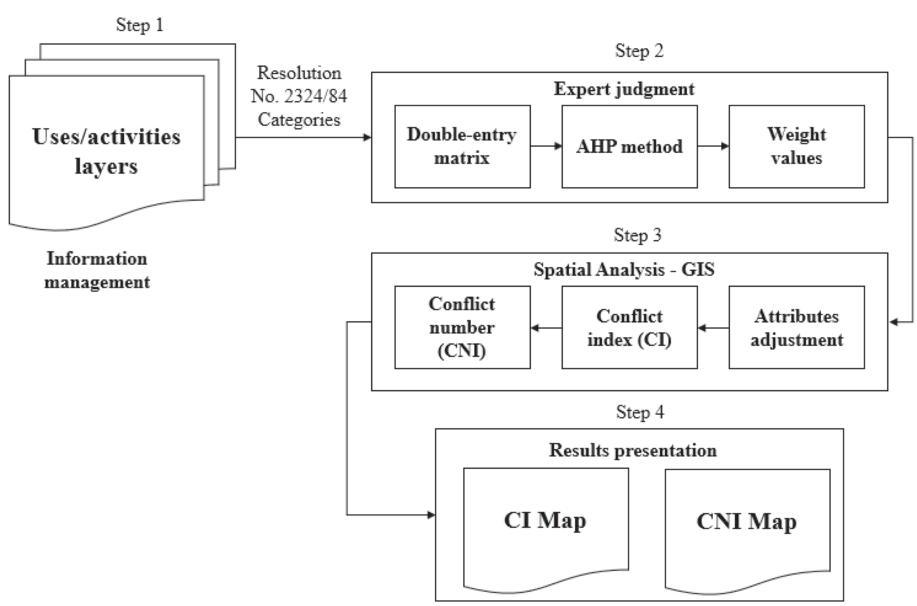

Figure 2. Flowchart for conflicts and synergies identification (adapted from Tuda *et al.,* 2014)
Figura 2. Diagrama de flujo para la identificación de conflictos y sinergias (adaptado de Tuda *et al.,* 2014).

different national and regional organizations (table 1) involved in ecological, socioeconomic, and environmental affairs. Part of the information obtained was free and available through the official websites and geoportals listed in table 1, spatial data infrastructure while others were directly obtained through collaboration and permits upon official requests.

The acquired information was stored in a geodatabase (ESRI 2018) for its management and analysis. Layers were grouped according to its use/activity, based on Decree-law No. 2324 of 1984 (Presidencia de la República de Colombia, 1984), which classifies each activity based on the proceedings of the Dimar as the maritime authority (table 2) in order to organize and analyze the data layers according to the sector classification. A total of 36 layers (shapefiles) were obtained, which roughly display the current scenario of the CP01 area. It is important to mention that some of the information that was obtained at different scales, geometry, and temporality. To standardize all information, a buffer was performed 200-meters from each side of the geographic data in points and lines, except for submarine cables, in which a 500-meter buffer was used based on resolution No. 204 of 2012 (Dimar, 2012) and as part of the security measures established in Colombian jurisdictional waters.

Multi-Criteria Decision Analysis, AHP Method

A double-entry matrix was designed confronting uses by pairs (in rows and columns) to evaluate each activity according to the prioritizing use in the area. A quantitative ponderation was made between each pair of uses/activities, guided by the AHP proposed by Saaty (1990). The evaluation was made by a non-homogenous group of experts selected to weight the criteria (Elliott *et al.,* 2018). Based on their professional experience conformed by 11 experts in biology, environmental science, marine hydrographs, and engineers from the Pacific Oceanographic and Hydrographic Research Center (CCCP - Centro de Investigaciones Oceanográficas e Hidrográficas del Pacífico) in Colombia. This matrix was graded with

Table 1. Sources of geographic data information at the national level
Tabla 1. Fuentes de información sobre datos geográficos a nivel nacional.

Geoportals/ information systems	Institute	Website
Sistema de Información Ambiental de Colombia - SIAC	Environment and development ministry - Colombia	http://www.siac.gov.co/
Infraestructura de Datos Espaciales Marítima, Fluvial y Costera de Colombia	General Maritime Directorate	https://geohub-dimar.opendata.arcgis.com/
Visor Geográfico de Parques Nacionales Naturales - PNN	System of National Natural Parks	https://mapas.parquesnacionales.gov.co/
Geoportal de la Agencia Nacional de Hidrocarburos-ANH	National Hydrocarbon Agency (ANH)	https://www.anh.gov.co/Geoportal
Sistema de Información Geográfica para el Ordenamiento Territorial Nacional-SIGOT	The Agustín Codazzi Geographic Institute, IGAC	https://sigot.igac.gov.co/
Sistema de Información Ambiental Marina - SIAM	Marine and Coastal Research Institute (INVEMAR)	https://siam.invemar.org.co/

Table 2. Marine and coastal uses/activities identified in the study area.
Tabla 2. Usos/actividades marinas y costeras identificadas en el área de estudio.

Groups	Uses and/or activities	Description
Navigation and communication	Port concessions	Maritime affairs, navigation, and routes.
	Maritime concessions	
	Anchorage area	
	Navigation canals	
	Ballast water discharge area	
	Buoys and lighthouse	
	Submarine cables	
	Docks	
	Cabotage routes (Regional and local)	
	White catch fishing routes	
	Deep shrimp fishing routes	
	Shallow shrimp fishing routes	
	Small pelagic fishing route	
	Tuna fishing routes	
Fishing resource	Small scale fishing grounds	Small scale and industrial fishing spots.
	Industrial fishing grounds	
Biological value	Marine fauna	Areas were biological resources have been identified.
	Oceanic corals	
Leisure and entertainment	Beach management and zoning	Beach zoning regarding tourist activities.
Oil and gas industry	National Hydrocarbon Agency (ANH) lands	Areas destined for hydrocarbon activities.
Scientific research	Marine bottom floor exploration	Areas where technical seismic explorations are being performed with heat flow and piston core.
	Sandy seabed	Seabed identified as habitat for marine fauna.
	Non coral hard seabed	Hard substrate identifed as habitat for marine fauna
Political divisions	Beaches and low tide areas	Areas delimited by the Dimar in the Colombian resolution No. 2324 of 1984 (Presidencia de la República de Colombia 1984)
Special regulation	Afro Colombian communities	Presence of afro Colombian communities.
Conservation areas	SINAP (National System of Protected Areas in Colombia)	Coastal, Marine and Regional Protected Areas part of the Colombian National System-SINAP.
	Ecological and biological significant Marine Areas (EBSA)	Areas important to conservation because of their ecological and biological characteristics.
Coastal ecosystems	Mangroves	Main ecosystems found in flooding areas.
	Coastal swamp forest	Ecosystems in coastal flooding areas.
Other ecosystems	Shrub swamp	Natural coverage.

the use of expert judgment through a guided survey, responding: to the most important use: A or B? The weighting of each pair of uses was done with the fundamental scale developed by Saaty (1990) (table 3).

Once the matrix was graded by all experts, values were normalized through multiple simple algebra operations. Additionally, the sum of all rows was calculated to determine the weight (W) of each use/activity in the exercise. The sum of all weights must equal 1.

Conflict analysis

Conflict Index (CI) and Conflict Normalized Index (CNI)

Conflict Index (CI) was determined by the sum of the values of the weights of each pair of uses confronted in the matrix (Equation 1). Within the spatial analysis, when layers were intersected, the values considered were the ones assigned to each pair of uses and operated through the attribute table assigned to each layer (Equation 1).

Table 2. Marine and coastal uses/activities identified in the study area.
Tabla 2. Usos/actividades marinas y costeras identificadas en el área de estudio.

Groups	Uses and/or activities	Description
Aquatic ecosystem	Estuaries	Areas important for the conservation of strategic ecosystems.
Natural terrestrial ecosystems	Rain forests	Main terrestrial ecosystems.
Transformed terrestrial ecosystems	Agroecosystems	Ecosystems that have been partially or totally transformed.
	Fragmented forest	
	Secondary vegetation	
	Artificialized areas	

Table 3. Saaty fundamental scale.
Tabla 3. Escala fundamental de Saaty.

Value	Importance	Preference
9	A is extremely more important than B	A is extremely better than B
7	A is noticeably more important than B	A is noticeably better than B
5	A is more important than B	A is better than B
3	A is slightly more important than B	A is slightly better than B
1	A is equally important as B	A is equal to B
1/3	B is lightly more important than A	B is slightly better than A
1/5	B is more important than A	B is better than A
1/7	B is noticeably more important than A	B is noticeably better than A better than A
1/9	B is extremely more important than A	B is extremely better than A

$$CI = W_{U1} + W_{u2} \quad (1)$$

Where:

CI = Conflict Index.

W_{u1} = Weight of use$_1$.

Wu_2 = Weight of use$_2$.

Defined as the product between the difference of each *CI* and the subtraction obtained from *CI* with the minimum value and the *CI* with the maximum value (Equation 2); this was performed with the purpose of obtaining all values between 0 and 1 and categorized based on the value of the *CNI* identified (table 4).

$$CNI = \frac{CI_1 - CI_{min}}{CI_{max} - CI_{min}} \quad (2)$$

Where:

CNI = Conflict Normalized Index.

CI = Conflict Index.

CI_{min} = Minimum value of CI of a pair of uses.

CI_{max} = Maximum value of CI of a pair of uses.

Number of conflicts

The number of conflicts identified in an area was calculated using the geoprocessing tool from ArcGIS (ESRI, 2018), in which, a classification based on the number of conflicts (table 5) was performed. Additionally, based on each expert judgment, synergy areas between uses and the environment were identified in the study area.

Table 4. Category classification for CNI.
Tabla 4. Clasificación de la categoría del ICN.

Category	CNI Value
Low	0 – 0.25
Medium	0.25 – 0.5
High	0.5 - 1

Table 5. Category classification based on the number of conflicts identified.
Tabla 5. Clasificación de categorías sobre el número de conflictos identificados.

Category	N° conflicts
Low	1 - 3
Medium	4 - 6
High	> 6

3. Results

Marine and coastal uses identified

A total of 36 uses/activities grouped into 14 categories were identified in the study area of CP01- Buenaventura master harbor and its jurisdiction. Some of the geographical information obtained is limited to a specific time frame and a spatial distribution, therefore, this information may be subject to changes in time. Nevertheless, for the scope of this research, the current scenario presented implied as a result of the proposed methodology and its impact.

Conflict Index (CI) and Conflict Normalized Index (CNI)

A total of 105 overlaps were identified within the geographical data analyzed, in which 88.22 and 6.72% were categorized with a Low and Medium CNI respectively, indicating that 94.95% of all the uses and activities in the study area are moderately compatible (not categorized with a high CNI). Only 5.04% of the spatial data analyzed was evaluated with a High CNI, corresponding specifically, to the coastal area in the Málaga bay area and northeastern part of the same bay, additional to the coastal area in Bajo Baudó in the Chocó department (figure 3). Likewise, a high conflict index is displayed in the surroundings of the Malpelo Island, part of the SINAP (National System of Protected Areas in Colombia). table 6 presents a summary of the 13 conflicts with the highest value of CNI in the study area.

Within the conflicts identified with the highest CNI, several sectors are represented, with the majority, 76% (10) being part of the communication and navigation division assigned to the maritime authority either directly or indirectly, and the conservation areas (SINAP). Other sectors represented in the analysis are fishing resources, oil and gas industry, and scientific research, all with only one use evaluated in the highest CNI and representing 7.6% each showing incompatibility again with the conservation areas division. The analysis did not show incompatibilities within the same group or sector, or incompatibilities between two uses, with one being attached to a different sector other than conservation areas.

Number of conflicts

When identifying the number of activities that overlap in the study area, 87.03% overlap with a low degree, pointing out the intersection with less than three activities, while 12.97% present medium overlapping with other activities (at least 4 uses and activities). This situation is mostly represented in the center-north and southern areas of the EEZ, southwest of the Buenaventura Bay and near the San Juan River Delta (figure 4).

Additional results of this analysis showed 28 possible synergies on the overlapping uses (figure 5). These uses/activities have some type of compatibility by sharing common targets, like conservation and biological resources (biological value and conservation areas) or socio-economic (Navigation and communication and Fishing resource), mainly.

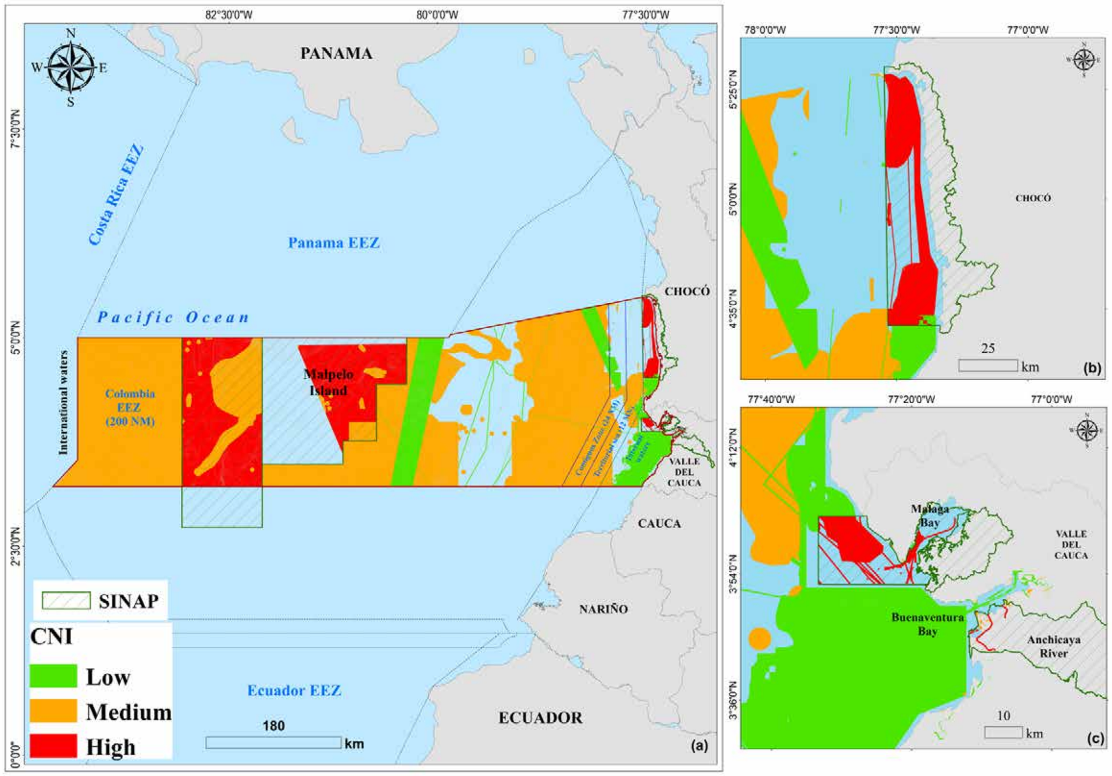

Figure 3. a) Spatial distribution of CNI in study area, b) zoom in to the Bajo Baudó in the Chocó department inside the study area and c) zoom in to the Buenaventura and Málaga Bay in the Valle del Cauca department in the study area.

Figura 3. a) Distribución espacial del ICN en la zona de estudio, b) Detalle del área del Bajo Baudó en el departamento de Chocó dentro del área de estudio y c) Detalle del área de las Bahías de Buenaventura y Málaga en el departamento del Valle del Cauca en el área de estudio.

4. Discussion

One of the most important results of this research is the continuous participation of the SINAP (conservation areas) as a common denominator in the high conflict category analysis, this points out the pressure that strategic ecosystems are subjected to due to a diverse array of anthropogenic activities (Bruce and Eliot 2007). The results of a similar conflict analysis that was also conducted by means of an AHP approach in the Caribbean Region of Colombia identified the SINAP areas as the use (conservation use) that most contributes to the conflict with respect to the other 55 uses present in that area (Afanador *et al.*, 2019).

These findings show opportunities for the environmental ministry to discuss agreements with other sectors to achieve sustainable development by establishing zoning that includes multiple-use areas performing co-allocation of conservation and eco-

Table 6. Conflicts identified with the highest CNI.
Tabla 6. Conflictos identificados con el CNI más alto.

No	Incompatibility Uses and/or activities	CNI
1	National Hydrocarbon Agency (ANH) lands // SINAP	1
2	Marine bottom floor exploration // SINAP	0.984
3	Submarine cables // SINAP	0.933
4	Cabotage routes // SINAP	0.898
5	Industrial fishing grounds // SINAP	0.898
6	Buoys and lighthouses // SINAP	0.894
7	Navigation canals // SINAP	0.894
8	Tuna fishing routes // SINAP	0.89
9	Deep shrimp fishing routes // SINAP	0.886
10	Small pelagic fishing route // SINAP	0.875
11	Shallow shrimp fishing routes // SINAP	0.875
12	White fishing route // SINAP	0.875
13	Anchorage area //– SINAP	0.867

nomic activities. Therefore, this exercise also serves as technical input to stakeholders and actors in the environmental sector in the study area. For example, results in this analysis pinpoint the incompatibilities among the protected areas and other activities that may be socio-economically important to a country's priorities.

Additionally, our findings suggest that industrial fishing routes and fishing grounds do not avoid the usage of protected areas, while at the same time, cabotage routes and the activities derived from touristic boats and the transport of passengers, also exert additional pressure over protected areas on a daily basis. It is important to mention that within the study area, specifically in the coastal area that has been declared national natural park (or any conservation and jurisdictional figure), the environmental authority and the implementation and regulation corresponds to the environmental ministry or sector which has complete autonomy and self-governance.

The maritime activities in charge of Dimar (as a maritime authority) such as the anchoring areas, buoys, lighthouses, navigation channels and submarine cables, presented a high IC; When these activities were assigned, a spatial planning approach was not considered, so their location can generate conflicts with other uses. The identification of these conflicts is essential for the management of the area and for the correct assignment of new uses.

Nevertheless, in other countries, this type of process has been used as a method for the correct assignation of specific locations needed for a particular use, such as a study in the Bay of Biscay in Spain and France, where Galparsoro *et al.* (2012) conducted an analysis under the MSP approach to provide the identification of the most suitable location for a Wave Energy Converter using GIS tools and the use of technical, environmental, and socio-economical layers. Other examples include a spatial model for marine park zoning in order to achieve conservation objectives under variant levels of resource use in Western Australia's Shark Bay (Bruce and Eliot 2007), exemplifying the integration of marine spatial planning to balance economic development and

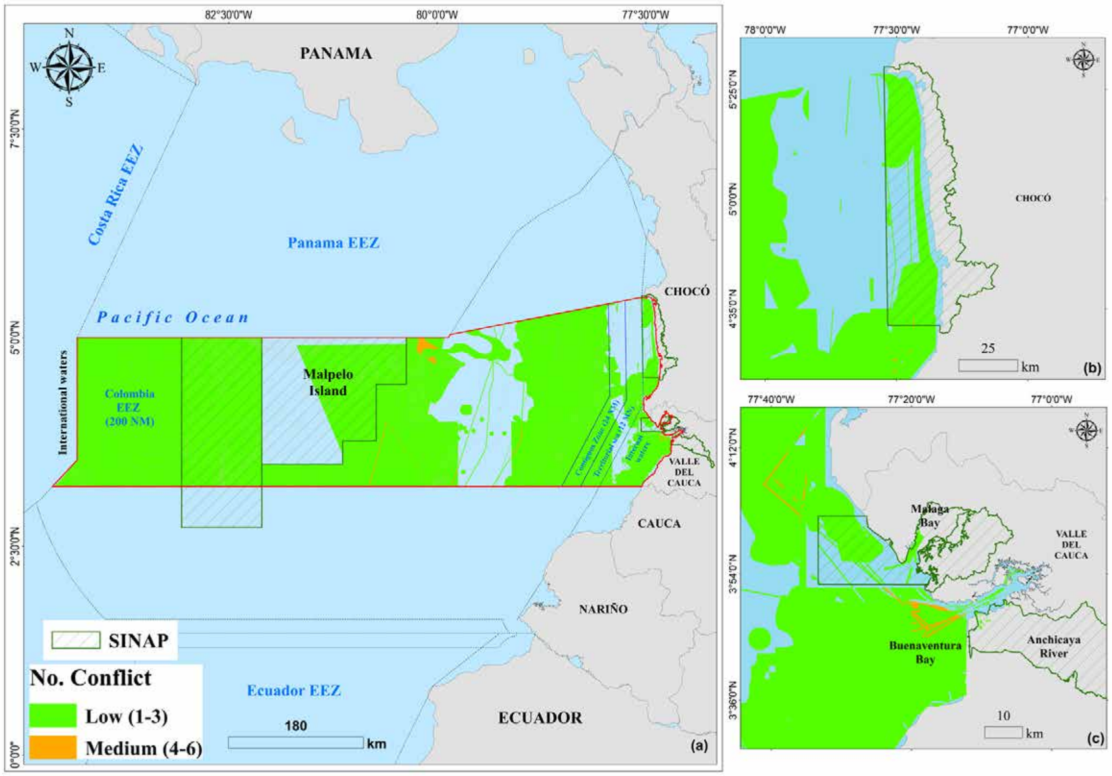

Figure 4. a) Spatial distribution of the number of overlapping uses/activities in the study area, b) zoom in to the Bajo Baudó in the Chocó department inside the study area and c) zoom in to the Buenaventura and Málaga Bay in the Valle del Cauca department in the study area.
Figura 4. a) Distribución espacial del número de usos/actividades superpuestas en el área de estudio, b) Detalle del área del Bajo Baudó en el departamento de Chocó dentro del área de estudio y c) Detalle del área de las Bahías de Buenaventura y Málaga en el departamento del Valle del Cauca en el área de estudio.

meeting conservational goals on the long term without the generation of any potential conflict.

Both, submarine cables and seismic exploration areas concerning marine bottom and available lands for off-shore exploration use that overlay the marine protected areas jurisdiction of the Colombian SINAP, were identified with a high degree of conflict because of the pressure they exert over marine ecosystems and the potentially harmful effects over the resident fauna. For example, the possible ecological effects of cable installation and operation which includes influence of physical fields on macrofauna and migrating fish, the chemical effects related to the release of toxic chlorine from anodes and mechanical damage to marine life on the bottom (Andrulewicz *et al.,* 2003), long-term exposure to magnetic fields of electrical currents induced by underwater sea cables (Bochert & Zettler 2004) or even the physiological malformations effects on benthic marine fauna due to seismic exploration (Aguilar de Soto *et al.,* 2013; Carroll *et al.,* 2017) in addition to other long-term potentially harmful effects on the local biodiversity that have not been considered.

Furthermore, possible synergies were identified based on expert judgment, in which, activities that can be socially and economically beneficial. These

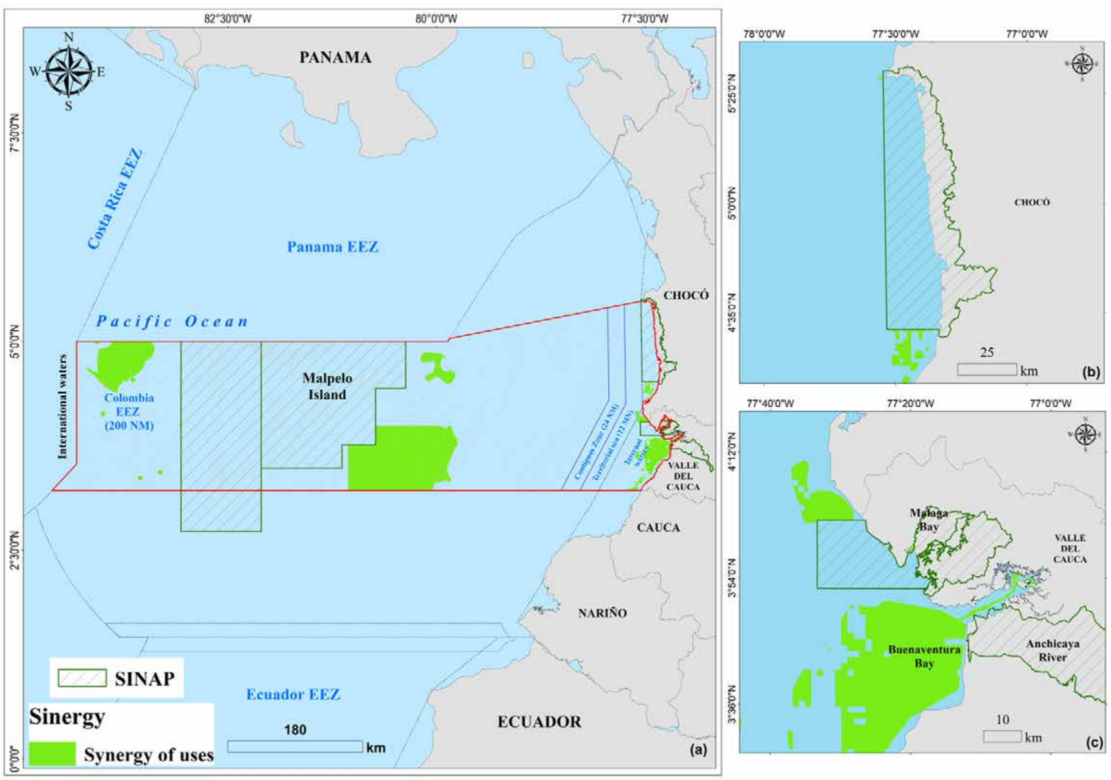

Figure 5. a) Spatial distribution of the Synergy of overlapping uses/activities in the study area, b) zoom in to the Bajo Baudó in the Chocó department inside the study area and c) zoom in to the Buenaventura and Málaga Bay in the Valle del Cauca department in the study area.
Figura 5. a) Distribución espacial de la Sinergia de usos / actividades superpuestas en el área de estudio, b) Vista ampliada del Bajo Baudó en el departamento de Chocó dentro del área de estudio y c) Visya ampliadade las Bahía de Buenaventura y Málaga en el Departamento del Valle del Cauca en el área de estudio.

analyzes must be carried out rigorously with the use of participatory tools. In this sense, with a good stakeholder's engagement in the planning scenario within the CP01 jurisdiction, these synergies may evolve into the establishment of co-allocation or multiple-use zones for these activities because they are compatible in time and space (Kyvelou & Ierapetritis, 2019).

The double-entry matrix constructed in this study is an important input for synergies identification between uses and activities which were intrinsic on the relationships shown by our results but could have been unknown by the experts, and potential areas to develop projects for conservation and economic activities that can be collocated without conflicts among users (Gimpel *et al.,* 2018). Additional to the conflicts identified within the study area, this study has evidenced the need to establish MSP process with a cross-border emphasis due to the fact that human activities are carried out up until the last mile of the marine frontier and in some cases, conflicts may arise between neighboring countries (transnational issues, calling for transboundary MSP possess).

This type of spatial planning has been conducted before nevertheless, it possesses specific challenges (Kannen 2012). but is of great technical value when specific potential uses, and activities are included in the binational agendas and are established as an international cooperation priority. Although this exercise was limited to the Colombian jurisdiction and the results presented here are not directly a trend scenario into the middle or long term, it does reflect a possible scenario on specific areas of special attention. This first exercise was done in a multi-scale way with data obtained from different sources and temporalities, due to the limited geographical information, and possess a caveat in the study scale in the exercise (Stamoulis & Delevaux, 2015) due to the fact that the quality of the geographic data access allows the management of the coastal and marine zones efficiently complemented with local knowledge as a source of geographic data that can be included in the process of the MSP (Prestrelo & Vianna, 2016).

Finally, the implementation of the MSP process in the jurisdiction of the maritime authority, such us our study area in this exercise, is an input that will foster the zoning of anthropogenic activities and uses, and therefore, establishing specific policies regarding maritime affairs. Although this exercise was conducted in a data-limited area, it provides decision-makers with baseline information, and is a starting point to marine and coastal planning of the Colombian coastal zone, that needs to become a national priority. On the other side, these results would serve as a baseline to bridge the gaps of available geographical information in the study area, specially, the information needed to identify spatial conflicts. More so, when implementing the adapted methodology to a data-limited region with Spatial Planning demands between different national sectors.

5. Conclusions

The use of GIS tools and MCDA enables the prioritization and the identification of conflicts in a simple but complete way, its application allows the spatial evaluation of conflicts of different uses and activities taken place in a study area and other possible incompatibilities that may arise with the environment, the inclusion of theses possible scenarios enables to perform analyses over several time periods.

In this study, the main conflicts identified were related to marine protected areas (included in the SINAP), these zones are considered especially important for ecology and biodiversity conservation. However, some strict conservation measures could go against economic activities that can be developed in a sustainable way. Agreements between actors that carry out these activities could lead to the establishment of co-allocation or multiple-use zones for some activities that were initially considered incompatible. Integrating the interests and needs of all stakeholders and sectors involved is one of the MSP principles, for planning and the management of marine and coastal zones. Different worldwide processes have demonstrated that MSP is an effective tool in the identification of spatial conflicts derived from anthropogenic activities.

The availability and quality of geographic data from marine and coastal uses and activities are especially important for spatial analysis and decision making. However, data gaps can be overcome using spatial analysis tools and expert judgment consultation.

This study reflects the first technical effort in the identification of conflicts and synergies of anthropogenic derived activities and uses in the jurisdiction of the CP01 in the Pacific coast of Colombia. A ponderation model and a spatial analysis were used to identify marine and coastal conflicts between uses of different sectors as a reflection of the scenario taking place in a geographical data-limited study area. Opportunities may arise out of this document in the use of MSP in the Eastern Tropical Pacific and neighboring countries.

6. Acknowledgments

This article was developed in the context of the "Planificación y Ordenamiento de los Litorales y Áreas Marinas Colombianas" project of the General Maritime Directorate – Dimar. Authors would like to thank Integrated Coastal Zona Management (ICZM) of Centro de Investigaciones Oceanográficas e Hidrográficas del Pacífico – CCCP in Tumaco-Colombia, for their collaboration, support and help with the data access.

7. References

Afanador Franco F, Molina Jiménez MP, Pusquin Ospina LT, Escobar Olaya GA, Castro Mercado I. 2019. Conflictos de uso en el proceso de ordenamiento marino costero: Visión de Autoridad Marítima. departamento de Bolívar - Colombia. *Boletín Científico CIOH,* 38(1):27-40.

Aguilar de Soto N, Delorme N, Atkins J, Howard S, Williams J, Johnson M. 2013. Anthropogenic noise causes body malformations and delays development in marine larvae. *Scientific Reports*, 3: 1-5.

Andrulewicz E, Napierska D, Otremba Z. 2003. The environmental effects of the installation and functioning of the submarine SwePol Link HVDC transmission line: a case study of the Polish Marine Area of the Baltic Sea. *Journal of Sea Research*, 49(4): 337-345.

Ban N. C, Bodtker K. M, Nicolson, D, Robb C. K, Royle K. Short C. 2013. Setting the stage for marine spatial planning: Ecological and social data collation and analyses in Canada's Pacific waters. *Marine Policy*, 39: 11-20.

Bochert R, Zettler M. L. 2004. Long-Term exposure of several marine benthic animals to static magnetic fields. *Bioelectromagnetics,* 25: 498-502.

Bruce EM, Eliot IG. 2007. A spatial model for marine park zoning a spatial model for marine park zoning. *Coastal Management,* 34: 17-38.

Burger J, Leonard J. 2000. Conflict resolution in coastal waters: the case of personal watercraft. *Marine Policy*, 24: 61-67.

Carroll AG, Przeslawski R, Duncan A, Gunning M, Bruce B. 2017. A critical review of the potential impacts of marine seismic surveys on fish & invertebrates. *Marine Pollution Bulletin Journal,* 114: 9-24.

Day J. 2015. In Transboundary Marine Spatial Planning and International Law 1st ed. London: Routledge & CRC Press. Chapter 6, Marine spatial planning: One of the fundamental tools to help achieve effective marine conservation in the Great Barrier Reef; p. 101-131.

Dimar. 1994. Resolución No. 0825. Por la cual se fijan los límites de jurisdicción de las Capitanías de Puerto. [accessed 2020 May 5]. https://www.dimar.mil.co/sites/default/files/normatividad/res_08251994.pdf

Dimar. 2012. Resolución No. 204. Por la cual se establecen áreas de seguridad a lo largo de los tendidos de cables submarinos en aguas jurisdiccionales colombianas. [accessed 2020 Feb 12]. https://www.dimar.mil.co/sites/default/files/normatividad/res_02042012.pdf

Douvere F, Maes F, Vanhulle A, Schrijvers J. 2007. The role of marine spatial planning in sea use management: The Belgian case. *Marine Policy*, 31: 182-191.

Ehler C. Douvere F. 2009. Marine Spatial Planning: a step-by-step approach toward ecosystem-based management. París: Unesco. Intergovernmental Oceanographic Commission IOC. Manual and Guides No. 53.

Elliott M, Boyes SJ, Barnard S, Borja Á. 2018. Using best expert judgement to harmonise marine environmental status assessment and maritime spatial planning. *Marine Pollution Bulletin*, 133: 367-377.

ESRI 2018. ArcGIS Desktop: Release 10.6. Redlands, CA: Environmental Systems Research Institute.

Fabbri K P. 1998. A methodology for supporting decision making in integrated coastal zone management. *Ocean & Coastal Management,*39: 51-62.

Frazão-Santos C, Agardy T, Francisco Andrade F, Calado H, Crowder LB, Ehler CN, García-Morales S, Gissi E, Halpern BS, Orbach MK, et al. 2020 Integrating climate change in ocean planning. *Nature Sustainability,* 3: 505-516.

Galparsoro I, Liria P, Legorburu I, Bald J, Chust G, Ruiz-Minguela P, Pérez G. 2012. A Marine Spatial Planning approach to select suitable areas for installing Wave Energy Converters (WECs), on the Basque continental shelf (Bay of Biscay). Coastal. 40: 1-19.

Gee K, Lukic I, Schultz-Zehden A, Ooms E, Ansong J.O, Passerello C, s.Pro. 2018. Considerations for MSP planners. Addressing conflicting spatial demands in MSP. Final Technical Study. European Commission. Brussels. 35p.

Gimpel A, Stelzenmüller V, Töpsch S, Galparsoro I, Gubbins M, Miller D, Murillas A, Murray AG, Pınarbaşı K, Roca G, et al. 2018. Science of the Total Environment A GIS-based tool for an integrated assessment of spatial planning trade- offs with aquaculture. *Science of the Total Environment Journal,* 627. 1644-1655.

Gourmelon F, Guyader DL, Fontenelle G. 2014. A dynamic GIS as an efficient tool for Integrated Coastal Zone Management. *ISPRS International Journal of Article Geo-Information*, 3: 391-407.

Kannen A. 2012. Challenges for marine spatial planning in the context of multiple sea uses, policy arenas and actors based on experiences from the German North Sea. *Regional Environmental Change*, 14(6): 2139-2150.

Kyvelou S S. Ierapetritis D. 2019. Discussing and analyzing "Maritime Cohesion" in MSP, to achieve sustainability in the marine realm. *Sustainability,* 11:12, 1-29.

Latash, M.L., 2008. Synergy. Oxford University Press.

Mcgrath K. 2004. The feasibility of using zoning to reduce conflicts in the Exclusive Economic Zone. Buffalo Environmental Law Journal Volume. 11(2): 183-218.

Moore S. A, Brown G, Kobryn H, Strickland-Munro J. 2017. Identifying conflict potential in a coastal and marine environment using participatory mapping. *Journal of Environmental Management,* 197: 706-718

Presidencia de la República de Colombia. 1984. Decreto Ley no 2324. Por el cual se reorganiza la Dirección General Marítima y Portuaria. [accessed 2020 Jan 28]. https://www.dimar.mil.co/sites/default/files/DECRETO 2324 DE 1984.pdf

Prestrelo L, Vianna M. 2016. Identifying multiple-use conflicts prior to marine spatial planning: A case study of A multi-legislative estuary in Brazil. *Marine Policy*, 67: 83-93.

Rojas X, Sierra-Correa PC, Lozano-Rivera P, López A. 2010. Guía metodológica para el manejo integrado de zonas costeras en Colombia, manual 2: planificación de la zona costera. Serie de Documentos Generales INVEMAR No 44. Santa Marta: Ediprint Ltda.

Rojas A M, Agudelo-Ruiz CA, Diazgranados CM, Polanco H, Anderson R. 2019. Approach to an integral valuation of mangrove's ecosystem services in a marine protected area. Colombian Pacific region. *Journal of Environmental Economics and Policy*, 8(3): 322-342.

Saaty TL. 1990. How to make a decision: The analytic hierarchy process. *European Journal of Operational Research*, 48(1): 9-26.

Smith G, Jentoft S. 2017. Marine spatial planning in Scotland. Levelling the playing field? *Marine Policy*, 84: 33-41.

Stamoulis KA, Delevaux JMS. 2015. Data requirements and tools to operationalize marine spatial planning in the United States. *Ocean and Coastal Management,* 116: 214-223.

Tsilimigkas G, Rempis N. 2018. Marine uses, synergies and conflicts. Evidence from Crete. *Journal of Coastal Conservation*, 22:235-245.

Tuda A. O, Stevens TF, Rodwell LD. 2014. Resolving coastal conflicts using marine spatial planning. *Journal of Environmental Management*, 133:59-68.

Vallejo-Borda J, Gutiérrez-Bucheli L, Ponz-Tienda J. 2014. Proceso analítico jerárquico como metodología de selección. aplicación para la selección de la mejor alternativa de almacenamiento de agua. V Seminario Internacional Uso Racional del Agua. Pitalito, Huila. [accessed 2020 Feb 21]. http://doi.org/10.13140/2.1.4596.3848

Wilmot W.W, Hocker J.L. (2007). Interpersonal conflict, seventh edition. New York, NY: McGraw-Hill.