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Web Atlas as a Tool for Coastal Integrated Management: from Data to Practical Knowledge

Web Atlas como Herramienta para la Gestión Integrada Costera: de los Datos al Conocimiento Práctico

Sílvia Maria Sartor[1], Marcos Reis Rosa[2], Juliana Tristão Pires[3], Claudio Augusto Oller Nascimento[4]

e-mail: silvia.sartor@usp.br

[1] Escola Politécnica, University of São Paulo, Brasil

[2] Faculdade de Filosofia, Letras e Ciências Humanas, University of São Paulo, Brasil.

[3] Programa de Pós-Graduação em Ciência Ambiental, University os São Paulo, Brasil.

[4] Departamento de Engenharia Química Escola Politécnica, University of São Paulo, Brasil.

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Abstract

Despite the importance of coastal areas to sustainable development, they are poorly known by the public or even by decision-makers. This undermines consistent action towards their protection. Existing data and information, published in very complex language, tend to be restricted to academic use. The Coastal Web Atlas as the one developed here is a tool that makes this information more accessible to managers, by preserving, integrating, comparing, and sharing data as smart maps. The spatial analysis based on multiple impact indicators facilitates the correlation of causes and effects. The Coastal Web Atlas is available to a broad audience and it could be a strong instrument for spatial planning and oversight. The authors propose to improve coastal area management by using colors on maps to decode scientific language to friendly language and to publish it on a geoportal. This technology promotes the use of collected data and enables collaborative work. A pilot experiment is being developed in the Santos Port Region, at the São Paulo state coast, Brazil: http://santoswebatlas.com.br/

Resumen
A pesar de la importancia de las áreas costeras para el desarrollo sostenible, ellas son poco conocidas por el público o incluso por los tomadores de decisiones. Esto socava una acción constante para su protección. Los datos y la información existentes, publicados en un lenguaje muy complejo, tienden a restringirse al uso académico. El Coastal Web Atlas, tal como se presenta aquí, es una herramienta que hace la información más accesible para los administradores, preservando, integrando, comparando y compartiendo datos en forma de mapas inteligentes. El análisis espacial basado en múltiples indicadores de impacto facilita la correlación entre causas y efectos. Un web Atlas Costero disponible para una amplia audiencia es una herramienta poderosa para la planificación y evaluación espacial. Los autores proponen mejorar la gestión de la zona costera utilizando colores en mapas para decodificar el lenguaje científico en un lenguaje amigable y publicarlo en un geoportal. Esta tecnología permite el uso de datos recopilados previamente y la construcción como un trabajo colaborativo. Se está desarrollando un experimento piloto en la Región del Puerto de Santos, en la costa del estado de São Paulo, Brasil: http://santoswebatlas.com.br/
Palabras clave: Evaluación de Impacto, Planificación Espacial Marina, RedIinternacional de Atlas Costero, Monitoreo Ambiental, Gestión Basada en Ecosistemas.

1. Introduction

The land areas adjacent to the world's shorelines house large and growing concentrations of people (EC, 2012; UN, 2017). About 37 percent of the world's population lived in coastal communities in 2017, and three-quarters of all large cities are located not far from the coast (UNEP, 2019; UN, 2016). Despite their rich environmental importance, coastal ecosystems are being severely degraded. As population density and economic activity in coastal zones rise, pressures on coastal ecosystems increase. Wetlands are drained and covered with litter, the floodplains around estuaries are built over and reduced, and mangroves forests are cut down. Ecosystems are damaged and frequently lost forever. Fish stocks and beach sands are overexploited, at great ecological cost (UN, 2016).

Many important activities in coastal areas have grown significantly in recent years, including those related to ports, oil production, the fishing industry, and construction, as well as booming coastal tourism (Food and Agriculture Organization (FAO) (1992). Among the most important pressures are habitat conversion, land cover change, pollutant loads, and the introduction of invasive species (Bierbaum *et al.,* 2012; ISSG, 2015). These pressures can lead to loss of biodiversity, coral reef bleaching, new diseases among organisms, hypoxia, harmful algal blooms, siltation and reduced water quality, and threats to human health (Glick *et al.,* 2013; Washington Department of Fish and Wildlife, 2015, Kauppi *et al.,* 2018; Gammal *et al.,* 2017, 2019). It is also important to recognize that high population density in low elevation coastal zones increases vulnerability to rising sea levels due to climate change (Nicholls *et al.,* 2007; Katsman *et al.,* 2008, 2011; Zanuttigh *et al.,* 2015).

Currently, most countries in the world (Morgan, 2012), require Environmental Impact Assessment (EIA) in order to obtain licenses for new ventures or operations in coastal areas (EC, 2016; Environmental Protection Agency 2015; IBAMA, 2019). The environmental licensing process is a legal requirement prior to the implementation of any project or activity that can potentially pollute or degrade the environment and it is important to sustainability because it involves the definition of how coastal areas can be used. A number of publications, including several books, address this issue in depth by exploring the various questions and issues involved (Canter, 1999; Lawrence, 2003; Duinker & Greig, 2007; Mahmoud et al., 2009; Tourki, Keisler, & Linkov, 2013; Cárdenas 2015, Borione et al., Sánchez 2020). They describe the trend in the adoption of EIA processes, efforts to make EIAs more practical, the decision-making scenario, public participation, and so on.

Social participation is the most significant feature of the decision-making process and public hearings are an important part of it (Brazil, 1987; Razzaque & Richardson, 2006; Parikh, 2017). Unfortunately, this participation is less effective than it should be because the interested community often cannot access or understand (when access is available) the language used in Environmental Impact Assessment (EIA) reports (Parikh, 2017) . The main difficulty is the text format. The EIA generates a number of reports addressing specific issues wrote by academic expertises. This data presentation does not effectively integrate the themes to allow a better understanding of the synergic impacts on the ecosystem. In addition, all those involved are under pressure to meet deadlines and are subjected to political and economic interests that require a better overall and systematic approach to publicly justify the directions taken.

Therefore, this work aims to show how marine coastal zone data can be better managed by means of a Coastal Web Atlas based on smart maps built with a set of color-coded impact indicators. With this methodology, the academic complex information is translated into maps that are easy to understand.

The proposed Web-Atlas provides technological mechanisms enabling geographic analysis that can help eliminate knowledge barriers. It provides real knowledge on the subject that will enable coherent arguments to demand change and more consistent action for environmental protection. The web atlas is structured on a geoportal that organizes the data and information on a unique platform that is user-friendly and encourages the sharing of data.

Sustainable development

Sustainability is subject to economic and social interests that are stronger than environmental concerns because involves basic needs so urgent that short-term responses are required (Beder, 2002; 2006; Steffen *et al.,* 2015). Because environmental changes are mainly felt in the long term, there is limited immediate awareness of their impacts and this undermines efforts to address them (Higgins, 2015; Reusch *et al.,* 2018). Consequently, the environment that ensures human well-being continues to be degraded. Environmental accidents occur frequently worldwide and are often the result of carelessness. An example of this occurred in November 2015 in Brazil, when an iron ore tailings containment dam burst and 35 million cubic metric tons of mud was released into the river spreading out over 600 kilometers where it spilled into the sea, affecting thousands of people, impacting fauna and flora and forever tainting the image of the companies involved in the disaster (Fernando *et al.,* 2016; Espindola *et al.,* 2019; Foesch, 2020)

Today more than ever, the media is alert to the danger of collective myopia and the high social and environmental cost of not acting preventively. Nevertheless, it is not easy to sensitize the community to unfamiliar matters. The situation is aggravated by society's ignorance of knowledge that is hidden on library shelves (even if virtual ones).

To reduce the paradox of having universities producing knowledge with public funds and this same knowledge being unavailable to the public, it is necessary to rethink paradigms. The environment needs to be dealt with more broadly as an important priority. In this context, technologies to minimize the distance between academic data and public knowledge are of great value and the Web-Atlas developed here will help to accomplish this. It is intended to promote an integrated understanding of ecosystems and improves knowledge of the environmental conditions simplifying the current approach to the presentation of EIA information.

Access to knowledge to promote change

Lack of access to and understanding of scientific information has been cited as obstacles to sustainable development (Henderson, 1996. Kingston *et al.,* 2000; Bhave *et al.,* 2016; IODE, 2017). Hey *et al.* (2009) calls the scientific production generated from existing data and researches the Fourth Paradigm.

In the discussion of environmental impacts and social risks caused by global warming, nothing will be more convenient than having the needed knowledge accessible on the internet in an user-friendly (IODE, 2017).

First, we need to distinguish "data" from "information" and "knowledge". "Data" are observable, raw values that result from research or technical collection activities and these values can be numerical (as in temperature or biodiversity indices) or nominal (as in species lists), and "information" is gained from data that have already been processed and interpreted (IODE, 2016). "Knowledge" consists of information in an integrated systemic context that provides a better understanding of the whole process. The Coastal Atlas proposed (http://santoswebatlas.com.br/mapas/) accumulated knowledge from a team of experts into each EIA bioindicator (deforestation level; animal-vegetal biodiversity and all ecological indices). Moreover, this knowledge is accessible as maps solving the challenges regarding the access to the results of science in a more open and interactive way. It increases the capability of governments to make decisions when they face complex challenges that are fast-moving and more interconnected than ever before.

The Motivation to develop the tool

The process of building a web-atlas based on geotechnologies was maturing (Sartor *et al.,* 2007), after twenty years of experience helping to produce Environmental Impact Assessments (EIAs) as data sources in coastal areas of the Santos region. The necessary procedures and developments were becoming more technically sound and appropriate to address the EIA challenges concerning knowledge uncertainties, process duration, and the difficulty of effective social participation in decision-making.

During these years it has been seen that since previously collected data was not stored, nor organized on a single platform, many ToRs (Term of References) required new studies of well-known themes while neglecting to ask for knowledge of other themes critical to ecosystem understanding. Another thing noticed was that the general public clearly could not understand the EIA data. The number of issues presented is very diverse and is not integrated to enable an analysis of whether the ecosystem can support the venture being considered for licensing. In addition, the experts use tables, graphs, texts, and statistical analyses that are not easily understood by common citizens or by managers. Analysts working on EIAs operate separately, each focused on a particular theme, as described by Bond *et al.* (2010). Even analysts find it difficult to understand issues outside their area of expertise, and this makes it hard for them to relate to each other. Consequently, scientific descriptions are ineffective in helping stakeholders understand ecosystem functioning.

Finding data from previous research is very frustrating. This knowledge is fragmented in many publications that are stored in many different places. Even when publications are found, there is often no access to the raw data. The efforts to access the raw data could require contacting the original researchers. Costanzo and Sánchez (2012, 2014) in their evaluation of the EIA process in Brazil, have shown that the most relevant repositories of knowledge are the researchers themselves (human repositories) and this is true even nowadays. This makes it very difficult to recover data and a great amount has been lost due to lack of registration. After research projects end, the records of the data collected often disappear. Consequently, although marine research is expensive, it is not unusual to incur additional costs to duplicate the data.

It was also noted that the reports were too numerous and complicated and this undermined the ability of the state officials responsible for issuing a license to understand EIAs results. In addition, there was an imbalance between the number of requests for licenses to use coastal areas and the number of government assessors in Brazil, with very few evaluators in light of the demand. There is also intense pressure from governments (federal, state, and municipal) to quickly grant licenses for public works (ports, highways, hydroelectric plants, submarine outfalls, etc.). Evaluators pressured by deadlines to issue an opinion on the licenses ended up condoning uncertainty in the knowledge reflected in the data presented in EIAs, bowing to political and economic pressures. After EIAs are approved, public hearings are held to allow input from civil society, non-governmental organizations (NGOs), local governments, universities, and so on. The EIA reports are available for stakeholders to review, but they often are unable to understand them. Consequently, even if there is empirical knowledge (from an artisanal fisherman, for example), indicating the harm that would be caused by the activity pending licensing, the lack of a convincing argument can undermine the ability to protect rights. It is common for companies requesting licensing to use the uncertainties of EIAs to confuse the public. Several surveys deal with EIAs in Brazil (Bond *et al.,* 2010; Costanzo & Sánchez, 2012) and other countries (Morrison-Saunders *et al.,* 2014; Koch & Weingart, 2016) found the knowledge available in EIAs to be ineffective. The conclusion was that this definitive model of study and processing of results has not worked properly. This situation generates worrisome deviations, such as PEC 65/2012, under discussion in Brazil, which aims to reduce environmental demands, arguing that the licensing processes are time-consuming (Brazil, 2018).

2. Materials and methods

Study Area - location and environmental problems

The area chosen to develop and test the new tool, the Santos region (figure 1), is a densely populated conurbation in Southeast Brazil, with over 1.7 million inhabitants (IBGE, 2010) living in its coastal urban zone. It is the closest resort city to the São Paulo metropolitan region of 20 million inhabitants, only 70 km away.

The largest port in Brazil or even in Latin America is located in the Santos estuary, an ecologically important ecosystem. Traditional subsistence fishing populations live and fish in the same estuary. It harbors an important petrochemical complex, a metal-

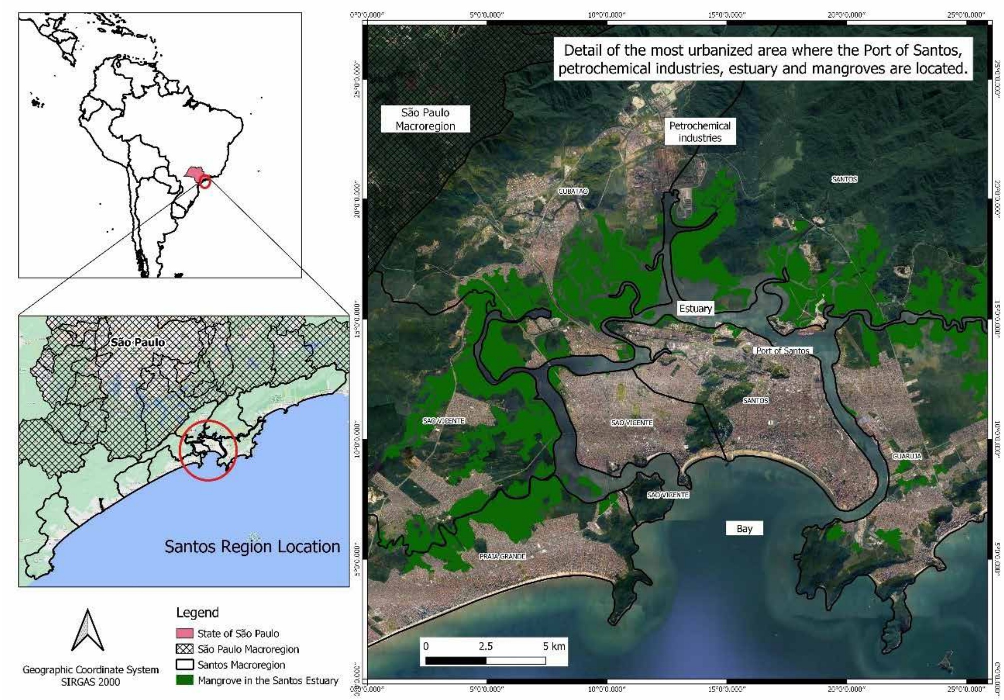

Figure 1. Santos Region Location
Figura 1. Ubicación de la región de Santos

lurgical complex, intense tourism, and industrial fishing activities, besides oil reserves recently discovered in the pre-salt sea basin of Santos. These economic characteristics of the Santos region result in intense demand for the use of new coastal areas, increasing applications for environmental licenses.During the 1960s and 1970s, there was rapid industrialization in the study area, which was not accompanied by adequate pollution control measures (Klumpp et al., 1994). Moreover, the environmental problems were aggravated by other factors, such as a lack of atmospheric pollutant dispersal due to the natural barrier created by the coastal mountains, the humid semi-tropical climate, and the atypical topography (56% hilly and mountainous terrain; 24% mangrove flatlands). The industrialization that took place had disastrous consequences on the Santos municipality, ranging from environmental to health problems (Hogan, 1995). By the end of the 1970s, Cubatão (the most industrialized municipality in the region - (IBGE, 2010), was widely recognized as one of the most polluted places in the world (Ferreira, 2007; Hardoy *et al.,* 2001). In 1982, an agreement between this city, the São Paulo state environmental regulatory agency (CETESB), and the plants in Cubatão resulted in the creation of the largest environmental control program in Brazil. By 1983, CETESB had identified 320 primary sources of air, water, and soil pollution and had established a strict timeline for the implementation of environmental controls.

Since the 1960s, studies have been carried out in this region to promote scientific knowledge and while some issues have been thoroughly studied, others have not (Sartor *et al.,* 2007). The data is fragmented and sometimes unpublished, which means that each new demand generates new studies, but the results are generally lost or misused. This explains the relevance of the proposed study, which organizes the data on a unique web geoportal – the Santos-Web-Atlas.

Coastal management - the role of web-based environmental spacialization systems

The integrated approach in coastal zone management is designed to achieve sustainability (UNCED, 1992) and ecosystem-based management of marine areas is a derivation of it. Geotechnologies have many advantages over conventional approaches in organizing and integrating repositories of datasets and disseminating them through the internet. Spatial Data Infrastructure (SDI), Marine Spatial Planning (MSP), and the Web Coastal Atlas (WCA) are geo-tools that incorporate management procedures and policies in different ways to help improve the usability of GIS by non-specialists and improve stakeholders` perception of the coastal environment, as well as their participation (Kopke *et al.,* 2011; Vasiliki *et al.,* 2013; Wright *et al.,* 2011).

A spatial data infrastructure (SDI) is a framework of geographic data and metadata that allows users to be interactively connected in order to use spatial data in an efficient and flexible way. Due to its nature (size, cost and the number of users), it is usually government-related (Meiner, 2010). SDI designed to disseminate marine data include the National Spatial Data Infrastructure (NSDI) in the United States, the European INSPIRE – Infrastructure for Spatial Information in the European Community (http://inspire.jrc.ec.europa.eu), the EMODNet – European Marine Observation and Data Network (www.emodnet.eu) described in Proctor & Howarth (2008) and Meiner (2010) and SeaDataNet (http://www.seadatanet.org). Kotsev *et al.* (2020) position SDI-related developments in Europe within the technological scenery. SDIs focused on marine areas are still incipient in most countries including Brazil, which possesses 8,500 km of coastline.

Marine Spatial Planning (MSP) is a UNESCO program started in 2006 with an approach that can make key components of ecosystem-based management of marine areas a reality, analyzing and allocating the spatial and temporal distribution of human activities to achieve ecological, economic, and social objectives that are usually specified through a political process (UNESCO-IOC, 2009). The Coastal Web Atlas (CWA) is also a portal for geographic information focused on the organization, integration, storage, sharing, and dissemination of information on coastal areas. CWAs have been developed to meet different objectives – to work as effective instruments in systematizing data and broadening the service for non-specialists (O'Dea *et al.,* 2011).

CWAs can be at different scales and they also can assist the development of Spatial Data Infrastructures (SDI). As an example, the Marine Irish Digital Atlas (MIDA) is a node within the Irish Spatial Data Exchange (Marine Institute *et al.,* 2011). With regard to MSP, CWA provides many of the required relevant data sets, mapping tools, and contextual information. An example is the California Ocean Uses Atlas overlaid with proposed Marine Protected Areas (O'Dea *et al.,* 2011).

The Coastal Web Atlas (CWA)

A Coastal Web Atlas (CWA) is a collection of digital and geographically referenced interactive map and datasets with supplementary tables, illustrations, and information that systematically illustrate the coast, often with cartographic and decision support tools, accessible via the internet and allows users to view and explore a wide range of marine and coastal data layers packaged in an intuitive interface that uses reliable state-of-the-art technology (O´Dea *et al.,* 2011; MIDA, 2015; ICAN, 2016). It is a practical tool for coastal managers.

CWAs can be connected to an SDI or MSP structure or completely independent, for a specific purpose and target audience. CWA features relate to design, data, technology, interoperability, collaborative work, coastal planning, management, interactivity, standardization, and software. Each CWA is designed differently, combining these features in diverse ways, and regardless of its design, the map area is its most important feature (O´Dea *et al.,* 2011) since it allows visualization of how the layers relate to each other spatially. Themes presentation in a CWA can be customized or lead to a web page with theme-related information and maps. Besides allowing layers to relate to each other, the web atlas has the challenge of overlapping them in a way that facilitates interpretation.

The great expansion of CWAs worldwide is due to ICAN (International Coastal Atlas Network), a community of practitioners (https://ican.iode.org/). The ICAN members cover a wide range of coastal topics and appeal to diverse audiences (https://ican.iode.org/es/sobre-ican/2-english/uncategorised/2-members-of-ican). The great challenge today is to develop a design that can be easily understood by coastal managers and decision-makers, and increase its use by non-specialists as well promotes accessibility by a wider public.

In 2013, ICAN became a project of the UNESCO IOC´s IODE (International Oceanography Data Exchange) program. According to ICAN-IODE (2013), the strategy is to share experiences and find common solutions to CWA development, working together to provide user and developer guides, handbooks and articles on best practices, information on standards and web services, expertise and technical support directories, education, outreach, funding opportunities, between others, while ensuring maximum relevance and added value for end-users. ICAN develops community-held constraints on mapping and data distribution conventions to maximize the comparability and reliability of information about coastal zones throughout the world.

3. The Santos-Web-Atlas description – the focused tool

Conceptual strategy of the Santos Web Atlas - Simplicity by color-code

The Santos Web Atlas (SWA) is the prototype produced as a tool to replace or supplement the EIA reports-based model (figure 2). It is the first CWA built worldwide for this purpose. It was developed to provide a better tool to the manager responsible for issuing licenses and also to democratize the information in a way that allows the interested public to understand the data and, consequently, increase the effectiveness of their wills in public hearings. The core aspect of the SWA tool is its decoding of environmental indicator impact levels as colors on maps so that they can be compared.

The SWA was built to be responsive to user needs. Consequently, the SWA must provide easier-to-understand knowledge about environmental conditions in areas pending licensing. It must offer all the data needed to understand each EIA focal theme, resuming all knowledge that experts often produce when following the traditional EIA model. Also, it must allow comparison of themes to promote understanding of the factors that lead to impacts (cause vs. effect).

The end goal of the authors is to encourage data sharing and additional data aggregation from expert teams responsible for ongoing updates and maintenance of their own themes, with different data of the region integrated into new maps. They also antici-

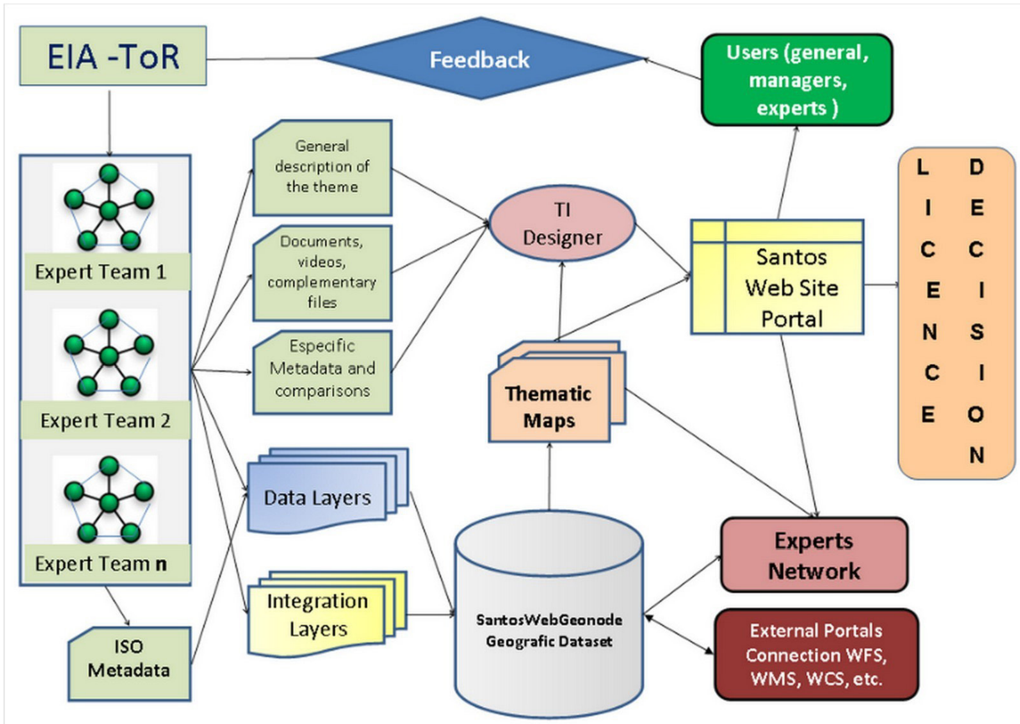

Figure 2. SWA diagram shows that EIA demands define focused themes according to the Terms of Reference (ToR) and its steps to built the license decision.
Figura 2. El diagrama SWA muestra los pasos para construir la herramienta hasta la decisión de licencia, de acuerdo con los temas cubiertos en los Términos de Referencia (TR)del EIA.

pate regular user feedback. Both actions are crucial to the success of the atlas.

Another advantage of the SWA is its capacity to indicate the not-yet-researched areas that need to be evaluated. The SWA model could definitely improve EIAs with respect to license definition, while at the same time making impact analysis less complicated. It also allows regular updating, forecasting changes and planning for the future.The user website is http://santoswebatlas.com.br/ and the geodatabase (the exports platform) is available at http://geonode.santoswebatlas.com.br/. Simplify academic complexity was the concept upon which the Santos Web Atlas was built.

Collaborative construction and data sharing benefits

The Santos Web Atlas GeoNode (http://geonode.santoswebatlas.com.br/) is a collaborative system. The data uploaded in shapefile, GeoTIFF, KML, and CSV to the geodatabase may be available to the public or only to specific users, according definitions of the thematic map author . The layers can be downloaded to local machines in JPEG, PDF, PNG, SHAPEFILE, GML, CSV, KML, or shared via standard OGC protocols such as Web Map Service (WMS) and Web Feature Service (WFS). This is vital to ensure compatibility and interoperability with other CWAs.

Data are included as layers and there is permission to control edit, delete, update and view functions. Any layer may have one or more cartographic representations saved and ready to use, using different colors, selection and symbols for specific attributes.

Data is available for browsing, searching, styling, and processing to generate maps. Any map may be saved on the SWA web interface and shared with the general public, including all information, standardized metadata and any other support material. Any update performed on the geonode map is instantly reflected on the portal.

All users share the same database and may use any layer that has been uploaded to the Geonode. This concept makes it much easier to keep the database updated.

The map concepts

Table 1 presents the improvements expected with this new approach by comparing it to the currently-use EIA model.

The maps are the core of the tool and are built based on the comparison of impacts that create indexes that are decoded to color. The standardization of colors used is an essential requirement to internationalize the methodology and to provide the visual comparison requisite. The map color proposed patterns are shown in table 2.

Color standard

The Environmental Impact Color Index (EICI) was created to provide a concise summary of the coastal conditions resources in the maps. This index is the comparative translation of each impact indicator to 5 color levels established in RGB standards (table 2). The index ranking to standardize the maps ranges from hot to cool colors. The standard colors, from most sensitive to least sensitive, are shown in table 2. These colors have been tested and optimized to provide the best contrast according to the NOAA in the Environmental Sensitivity Index (NOAA, 2002), adopted even in Brazil (Gherardi *et al.,* 2008).

This tool was configured to have five as the maximum number of colors used based on higher and lower values of each impact indicator. When referring to the ecological indexes such as biodiversity or animal community richness, for example, five classes are sufficient to distinguish environmental conditions. For some indices, like pollution, only the extreme two colors (dark green and red) are used, meaning that the impact index was below or above the standard legal and regulatory definition. In the case of pollutants in water, sediment or biota, it indicates whether the level is acceptable or not according to federal or international reference standards.

The data can be represented as points, lines, or polygons. Experts, map producers, and users define the best representation format in each case jointly. In designing a map to represent macrobenthos diversity or richness and bioindicators of sediment pollution, it was decided to represent the data as points that accurately reflect collection location. Taking user demands into account, the interpolation maps can be produced to allow a better understanding of the results. The IDW -Inverse Distance Weighted (Isaaks & Srivastava, 1989) was the index used for the macrobenthos interpolation map (figure 3).

Easy-to-understand language and user-friendly format

The main concept of the new tool is that the language must be easy to understand even by non-GIS operators. The focus is on the user. To achieve this goal, the key concepts for the proposed web atlas are:

a) data search must be fast; b) navigation must be easy and, most importantly, c) the impact level on the environment must be easy to understand.

Unlike the graphs produced from the complex multivariate analyses used in current EIA models,

	Table 1. Improvements of the Santos Web Atlas model compared to the currently used EIA model. **Tabla 1.** Mejoras en el modelo Santos Web Atlas en comparación con el modelo EIA utilizado actualmente.	
	Proposed product - SWA	**EIA Traditional product**
1.	Data is organized on a single platform and thematic maps may be compared.	Each set of data is presented in a separate chapter.
2.	Decodes search results in a friendly format - color maps linked to explanations	Results in academic language that is difficult to understand - texts, statistical analyses, graphs.
3.	Provides the impact analysis through infographics, relying on the expertise of senior researchers.	The impact assessment is textual and isolated in EIA-RIMA with no connection with the indicative data.
4.	Results are available on the web to download, copy or print	Results are available on files and paper
5.	The research of data is interactive and responsive	The research of data is time-consuming and displayed in isolated chapters
6.	Promotes an integrated understanding and access to raw data (thematic maps)	The data and information on environmental indicators are in separated chapters and original raw data is hard to acquire
7.	Promotes understanding of the ecosystem functioning	It´s hard to understand the ecosystem functioning because there are no spatial integration of the multiple aspects of the environment
8.	Maps may be downloaded in GIS format and correlated with other thematic maps	Maps, if available, are provided in PDF
9.	Facilitates correlation of causes and effects	Difficult to relate cause and effect (because the data is not displayed together)
10.	Greater flexibility in the product delivery	Product is performed by large staff and depends on the individual delivery of each section
11.	Competitive value because it uses a open-source software and enhances the use of existing data rather than incurring costs to acquire unnecessary data.	Currently requests that new data be acquired for each theme, even if it represents no new knowledge. Different project results can´t be visualized together
12.	Works as a data repository, perpetuating its use	No maintenance of original data. Each data provider retains its own information.
13.	Increases usage data - add value to previous data	Previous data may be inaccessible
14.	Avoids the need to collect data repeatedly on specific themes and locations. Lowers the costs of data acquisition.	Some themes such as fish, are repeatedly collected on the same site, while there is no data on other scientific areas that are also affected. Lacks studies on key issues.
15.	Establishes protocols to collect and process data that will be used on geoportals	No protocols to collect and process data. It is difficult to compare data. An example are the mangrove maps that provide no information about tide level. This precludes the comparison of maps to measure suppression area under the same tidal conditions
16.	Standardizes metadata according to the ISO.	No metadata standard is used
17.	High credibility since the data is reviewed by a team of experts.	Environmental assessment teams are established based more on cost than quality

Table 2. Environmental Impact Color Index (EICI) used in the maps
Tabla 2. Índice de colores del Impacto Ambiental (ICIA) utilizado en los mapas

Environmental condition	Impact Level	Color	RGB Standard
worst	extreme	red	209/77/80
bad	high	orange	248/163/0
average	average	yellow	255/232/0
good	light	light green	221/214/0
very good	very light	dark green	0/149/32

the SWA presents data in colors (Figure 3) and on smart maps that compare the data and information inserted and also allow comparison with data from other web publications.

The SWA design and technical structure

The Santos Web Atlas (SWA) was implemented using open-source software based on Python/Django including a combination of two different technologies (figure 4).

Portal website (http://santoswebatlas.com.br/)

The website for the general public provides a content management system based on Django Fiber which is an open-source tool that manages web-page content. It allows one to create simple textual, template-based pages, add simple content items in pages and views, and add simple reliable menus. All this can be maintained through easy front-end administration.

Data and map management (http://geonode.santoswebatlas.com.br/)

This platform can be used by experts to upload and download data and produce new maps. It is based on GeoNode (http://geonode.org/), which is a web-based application and platform for developing geospatial information systems (GIS) for deploying spatial data infrastructures (SDI) and web-based online maps. It is a collaborative environment that allows each registered user to upload data and explore, produce, style, and share maps. The data in this application is served using open standards endorsed by the Open Geospatial Consortium; in particular, WMS (Web Map Service) is used for accessing maps, WFS (Web Feature Service) is used for accessing vector data, and WCS (Web Coverage Service) is used for accessing raster data. WMC (Web Map Context Documents) is used for sharing maps.

The Santos Web Atlas has standard, manageable content and is specifically structured to display geographic data. Its structural architecture consists of the Home, About Us, Maps, Map Comparisons, Terms of Use, and User Evaluation (figure 5) http://santoswebatlas.com.br/ pages.

The maps are grouped into 3 categories: Physical-Chemical, Biological, and Socioeconomic.

Each map registered in the portal has to use a structure that ensures consistent information, which may include a brief description, the online maps, metadata, documentation, videos, and photos.

Description

A free text structure, which may include text, external links, images, graphs, and tables to describe the map. Go to http://santoswebatlas.com.br/mapas/balneabilidade/ to see an example of the theme description (the particularities of water quality concerning organic pollution and its relationship to rain cycles).

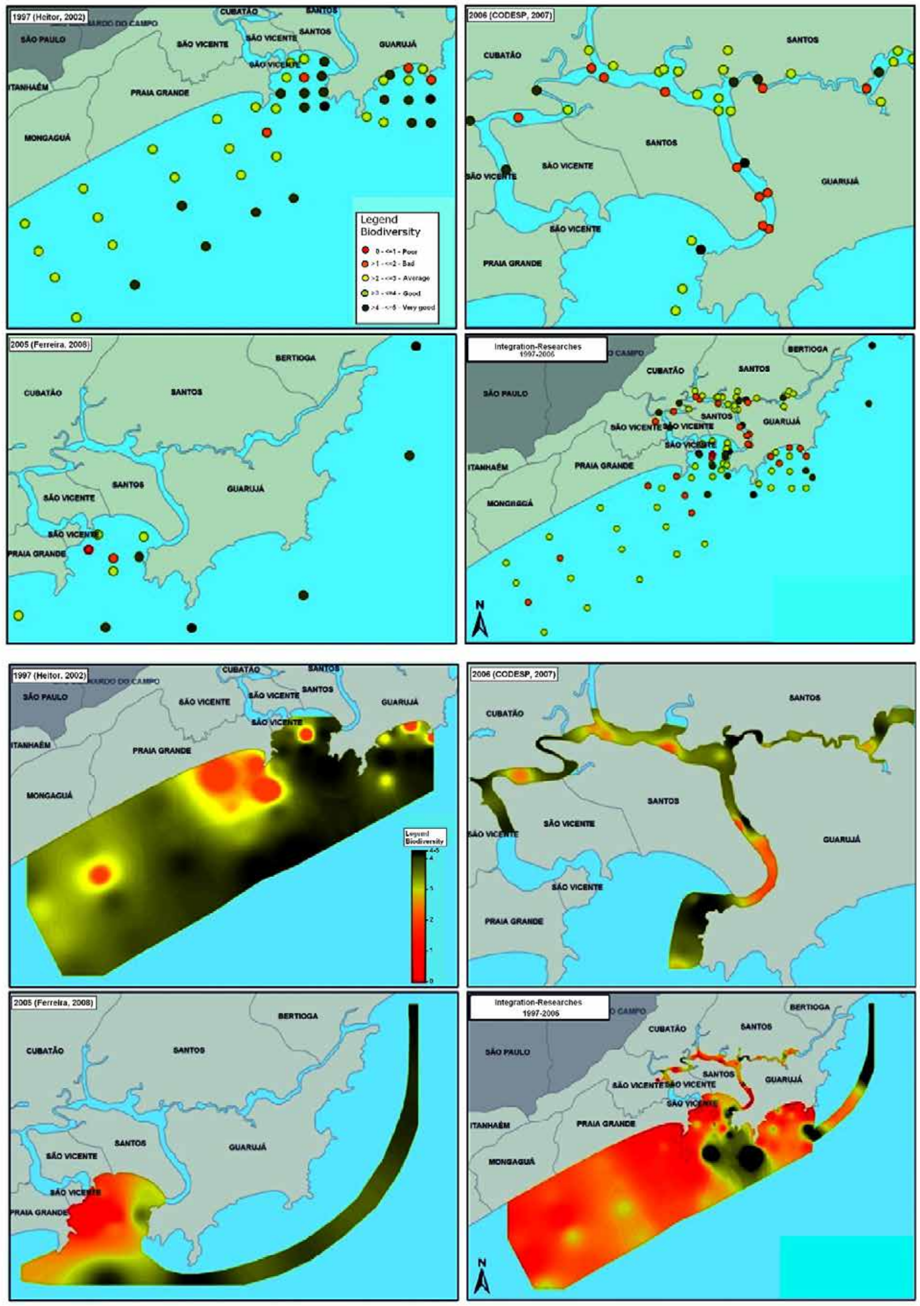

Figure 3. Model of SWA Maps. This one shows Shannon´s macrobenthos diversity. Above: Data indicated for each collection point. Below: Interpolated data. The spatialization of the 5-color collection result depicts what could only be previously interpreted via tables and graphs. Interpolation further facilitates understanding of the data.

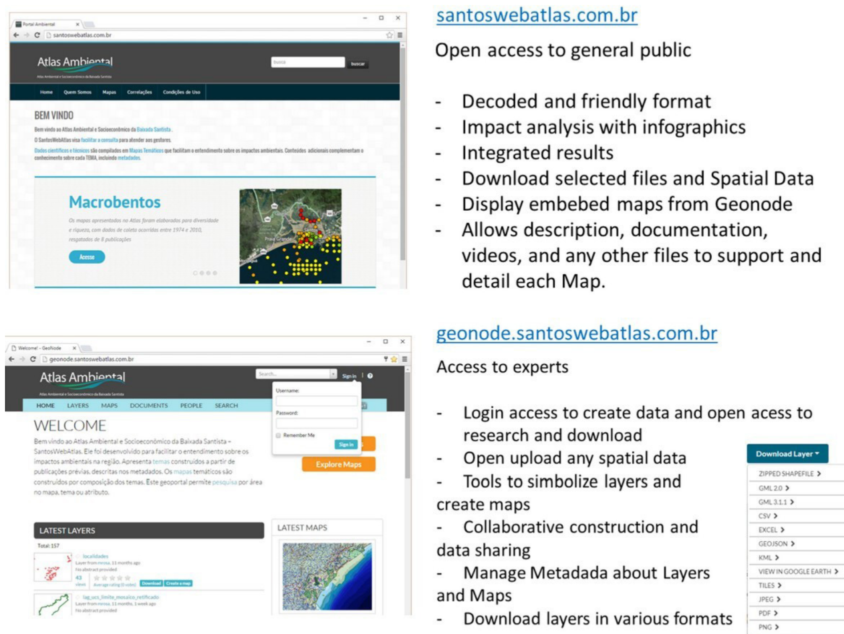

Figure 4. Presentation of the Santos Web Atlas portal website (above) and Geonode display (below).
Figura 4. Presentación del sitio web de SWA (arriba) y visualización de Geonode (abajo).

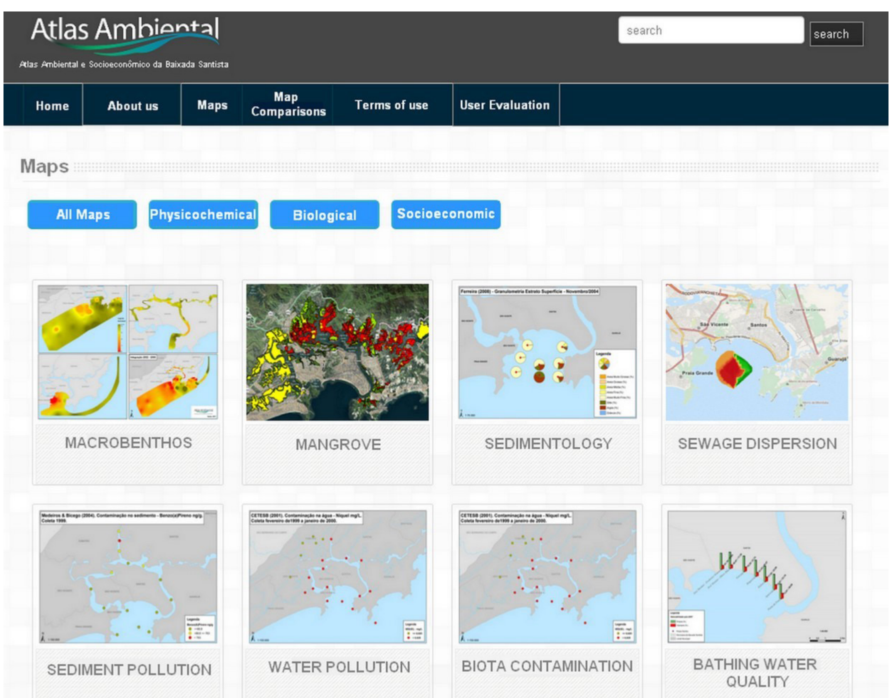

Figure 5. The Map menu as shown in Santos Web Atlas
Figura 5. Menú de mapa presentado en Santos Web Atlas

Map

The map is first loaded into the Geonode and then inserted into the SWA website using an iframe content code. This means that any upgrade performed on the GeoNode map is simultaneously reflected on the website. The thematic maps show layers in an interactive way, integrating several research studies. Figure 6 provides an example that indicates mangrove deforestation. At http://santoswebatlas.com.br/mapas/manguezal/mapa/cobvegetal/ one can check the layers in an interactive way. It allows one to see how the mangrove forest lost several ha of coverage between 1962 and 2009.

Metadata

Geospatial metadata is "information about data" (Federal Geographic Data Committee, 2017). In the SWA, as in other CWAs, the reliability of the data is provided by the metadata that captures the basic characteristics of a data or information resource. According to Dunne (2012), metadata helps users find the data they need and evaluate whether this resource satisfies their needs to help fully understand and interpret the data. Metadata documents the basic characteristics of a geospatial data resource, applications and services, falling into broad categories to answer the "what, why, when, who, where and how" questions about the resource. To operate effectively be-

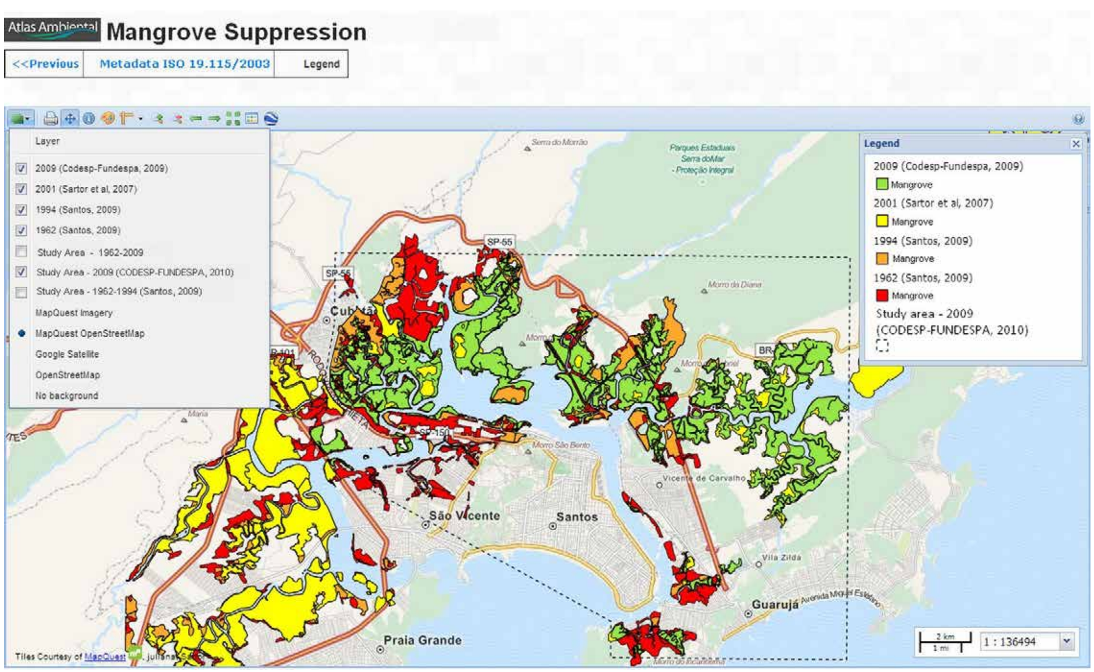

Figure 6. Mangrove Forest change between 1962 and 2009 based on an adaptation of data from three research studies (Sartor *et al.,* 2007; Santos, 2009; CODESP, 2010). Distinct colors for each research study make the analysis easier to understand.

Figura 6. Cambio en el bosque de manglar entre 1962 y 2009 a partir de una adaptación de datos de tres investigaciones (Sartor *et al.,* 2007; Santos, 2009; CODESP, 2010). Los diferentes colores para cada encuesta facilitan la comprensión del análisis.

tween different organizations and data users, metadata must comply with international standards that provide a common structure and format to describe metadata. Standards enable improved metadata interoperability and integration, thus facilitating more seamless sharing, searching, and discovery of metadata between organizations and users of geospatial data and services. Geonode imports the shapefile metadata from XML document (in ISO, FGDC, or Dublin Core format) to fill in key GeoNode metadata elements automatically. After the upload is finished, the user is presented with a form to fill in the metadata and it is made available using a CSW interface. Users may also download any layer metadata in XML document (in ISO, FGDC, or Dublin Core format).

Metadata in SWA

Metadata in ISO. (International Organization for Standards 19115/2003 or ISO 19.139:2007) is available for each layer in the SWA and presented to the general public through the toolbar on the maps application and metadata for each layer.

Data Summary. SWA also provides a detailed summary of the original study to supply sufficient data and general information. This avoids the need to search the original study to understand what is published on the thematic map.

Summary Table. SWA also has a table that compares each study and its elements, attributes, source, and characteristics. It includes the link to the original data and the link to download the data in shapefile or kml format if it is public. It is built to contextualize the data and data collection methodologies used for each source of information. The contents are defined by experts on the theme. This specific metadata consists of an abstract for each research study.

- **Documents/Videos/Photos.** Provides free content through the upload of complementary information with links to pictures, photos, videos and includes the ability to download PDF, DOC, or XLS files.
- **Tool Options – Smart Maps.** The SWA tools and underlying base map options are the standard for web GIS allowing one to access the list of layers, legends and associated data that does not appear on the maps, an information table and change the zoom level or print. The legends are built with the intention of facilitating understanding by managers (figure 7).
- **Identify.** This icon allows one to access attribute data and information associated with a geometric (point, line, or polygon). Attribute data in the table help promote understanding of the data represented. Tables can be moved from the original location. It is possible to make more than one query at the same time, opening several tables and comparing results (figure 8).
- **ZOOM Tools.** Using any of the zoom icons it is possible to control and change the scale of observation. The layer produced, if associated with the quality of images used as base maps allows the user to observe coverage textures of mangrove forests, sediment banks, neighborhood use or land occupation.
- **Documents Page.** This page has links to access the original studies and additional documents. Reports, original research, videos, photographs, graphs, tables, images, and others complement the map information. It is a data repository that stores and provides vector and tabular data. Through links you can access other geoportals, publications and other websites.
- **Map Comparisons Page = Correlation Page.** On this page the maps of different themes can be available to allow comparisons of sets of thematic maps according to specific needs. There is no limit to the number of layers that can be grouped. The limit is the user's ability to perform an analysis. Integration promotes overall under-

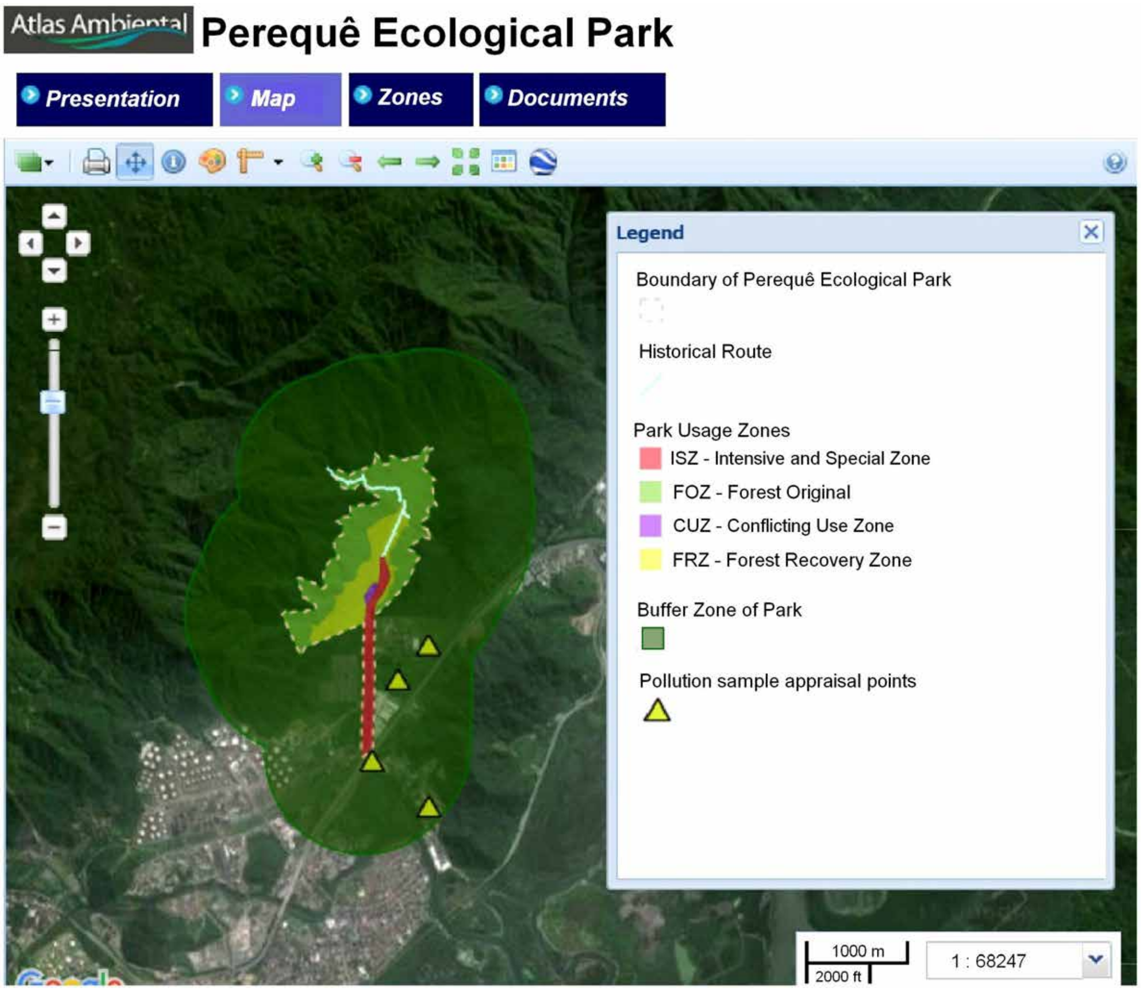

Figure 7. Example of associated legend in the Santos Web Atlas. Park management zones are shown.
Figura 7. Ejemplo de leyenda asociada en Santos Web Atlas. Se muestran las zonas de gestión del parque.

standing of the region. It is possible to analyze the combined ecological and social processes, identifying causes of impacts and priority areas for ecosystem conservation and traditional communities; to analyze biodiversity indicators with pollution and marine hydrodynamics; and to compare vegetation cover with Ecological Economic Zoning (EEZ), among many other possibilities. The SWA is developing tools to facilitate the choice of themes to be compared.

- **Evaluation Page.** The SWA has a page with a questionnaire that evaluates the opinion of users concerning SWA usability. This questionnaire evaluates the easiness of navigation and the understanding of impact levels. It also assesses how the new SWA product compares to the traditional EIA product. The questionnaire can be seen at http://santoswebatlas.com.br/mapas/questionario/questgoogle/

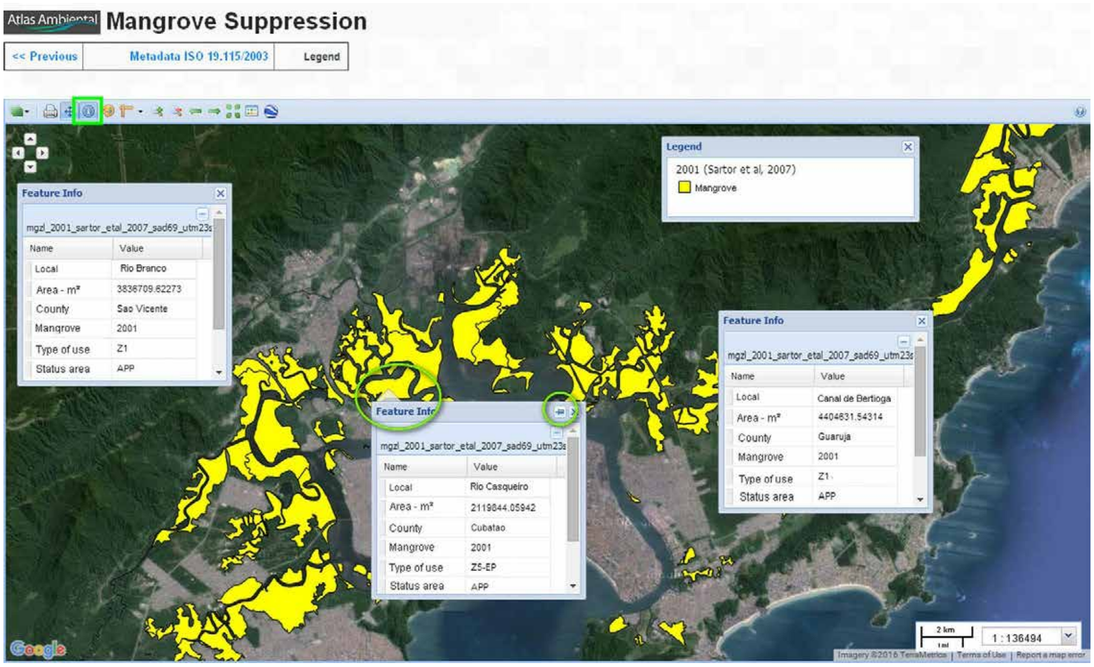

Figure 8. Example of associated information tables in Santos Web Atlas and the zoom display (up to 1:1,066 for mangrove)
Figura 8. Ejemplo de tablas de información asociadas en Santos Web Atlas y visualización de zoom (hasta 1: 1,066 para manglares)

4. Discussion

Santos Web Atlas user feedback

The group of users who answered the online questionnaire included environmental researchers (50%), environmental managers (25%), geotechnology experts (12%) and students in environmental fields (13%). The responses revealed that 78% felt that EIAs could benefit greatly from the Web Atlas tool. Among these, 12% considered that although the SWA promotes effectiveness, the report model for EIAs should also be continued. Most of the users were impressed with the improved understanding and speed provided by the maps. They recommended improving the legend display and some other features. They also recommended the insertion of a video tutorial and an automation tool for data graphing. The questionnaire ansewers can be seen at http://santoswebatlas.com.br/mapas/questionario/questgoogle/ .

The SWA design and content will be improved based on these users' recommendations and a better questionnaire strategy must be developed to encourage more feedback.

In 2013, a symposium to discuss the methodology used for marine and coastal area EIA and spatial-based tools provided useful information on the importance of the CWA for improving EIAs. The symposium took place in the city of Santos and was named Geotecmar - Geotechnologies for the Management of Marine and Coastal Areas: Integration and Sharing of Data Online. The main interest was to assess whether there was a need to review the Impact Assessment Model to license coastal areas in Brazil.

Three hundred people attended the symposium. Among the participants were environmental managers from several Brazilian environmental institutions. The symposium lectures are already available online at www.geotecmar.com., as well as a report of the results. During the symposium, a major revision of the EIA format was recommended. The conclusions of Geotecmar strengthened our commitment to building the tool model presented in this study. Subsequently, we continued to gain users' feedback from some governmental agencies: the Water and Sanitation Public Services and Control (SABESP), Forest Foundation, Marine Protection Areas and Environmental Prosecutor, Environmental NGOs and Environmental Advisory Committees. They express their interest in using the SWA model in their monitoring programs, adapting it to specific topics.

The SWA compared to other CWAs

The main distinguishing feature of the SWA compared to other web atlases is its decoding of environmental impacts in comparative language using color patterns to identify all relevant EIA topics. Another important SWA feature is the possibility of inclusion of all previous data available from research teams and its ability to summarize the knowledge on each topic and present it from a management perspective on maps with explanatory text and specific metadata. Several of these approaches already exist in CWAs but are isolated. The SWA is a new approach to EIAs, focusing on data recovery, not only as a repository of data and shapes display but also promoting understanding by geotechnology non-users about environmental changes in time and space.

The combined provision of images and location of structures or potentially impactful projects in SWA helps to compare the causes and effects (figure 9). The tool helps the data search and the integration layer provides spatial diagnostics that help to shape the environment.

Technological and human challenges in the development of the SWA

After a serious effort, we offer the SWA prototype as a good alternative to overcome the difficulties of the old EIA model. It can: a) organizes knowledge on a unified platform, b) structures and presents the knowledge in a simple format, c) allows the display of many layers using an interactive format, d) enables the addition of new data layers from research and visualization of correlations with different themes, e) considers the inter-relationships of the effects in a particular territory, and f) includes many information formats that are quickly correlated. A customized standard webpage appropriate for the final user was developed, as well as applications that improve data visualization layout maps and facilitate interactive consultation. It functions through a collective framework - where all those involved are part of a well-knit network - keeping data accessibility decentralized and maintenance and updating are dealt with by each responsible provider, following the same gateway, the SWA. Our philosophy is to assist in the acquisition, development and dissemination of geographic information that will, in turn, benefit all parties concerned as suggested by Tulloch (2008).

The creation of a new thematic map is one of the most difficult tasks of the SWA, since it requires the involvement of teams of experts, as well as payment for work related to data collection and processing. However, once the theme is published on the portal, other researchers are motivated to cooperate and add their data since this ensures increased visibility of their research studies.

Data sources, processing and standardization

to build a consistent web atlas to meet the needs of an EIA, all available data concerning each environmental indicator for better ecosystem understanding must be used. To develop each individual thematic

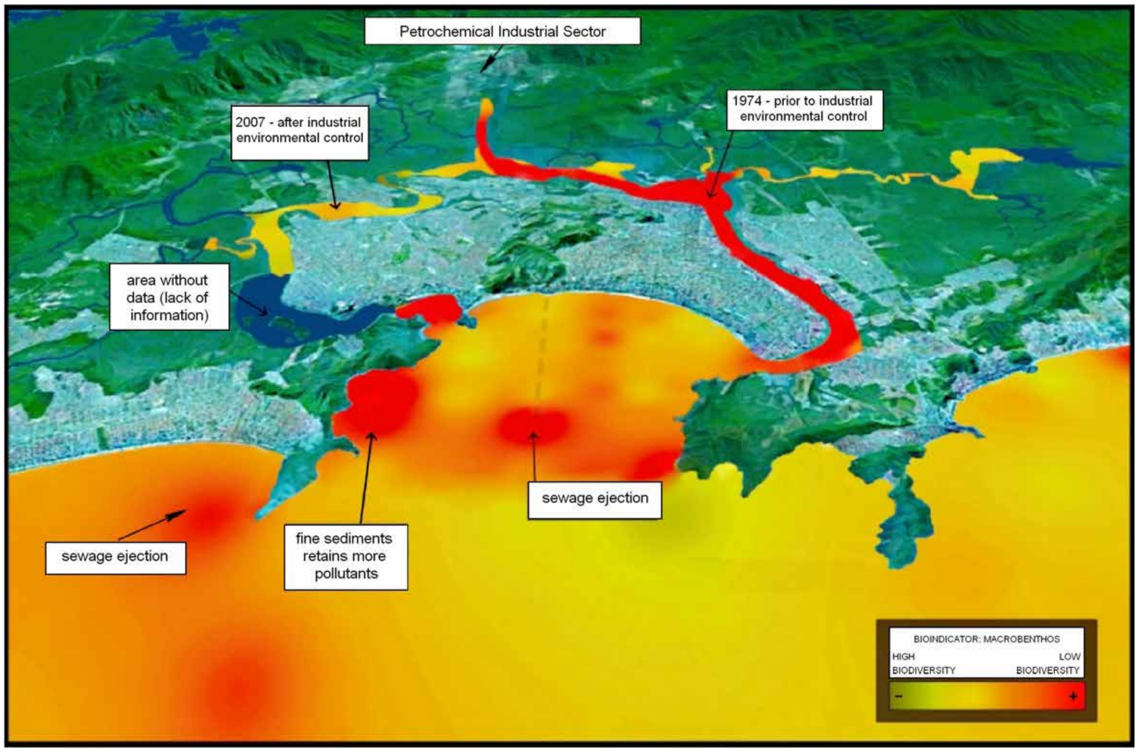

Figure 9. Map reflecting macrobenthos diversity showing color variations in space and times (Shannon indices). Repetition of impact levels of bioindicator diversity provided by different studies (1974, 2002, 2007) shows the likely source of impact (cause vs. effect) when compared with types of uses in the coastal zone.
Figura 9. Mapa de diversidad macrobentónica (índices de Shannon), reflejado en colores en el espacio-tiempo. La repetición de los mismos niveles de impacto sobre la diversidad de bioindicadores, en diferentes estudios (1974, 2002, 2007), muestra la fuente probable del impacto (causa vs. efecto) considerando los tipos de uso de la zona costera.

map, several layers reflecting the impact indicators must be built, one for each data set.

Multisource datasets, that are integrated, managed by different customers and incorporate different approaches taken by different studies, can lead to technical and non-technical difficulties in this integration. (Conti *et al.,* 2018). To be successful, it is necessary to recover and organize original data for each theme. This can be done only by experts who are in academia and busy with many daily activities with little time to take on new tasks. These experts can determine whether the layers should be organized for each acquisition date as seasonal, semi-annual, annual or even bi-annual and add information compiled in previous studies to a unique map. The involvement of experts is also essential to define protocols to be respected for data sources and to build specific metadata. This includes the need for additional data to complement knowledge about the issue impacted. The specialists' knowledge extends well beyond the overview of impact analyses. Frequently, problems arise from the way in which each research study must be individually analyzed, guided, integrated and applied. In addition, there are GIS concerns that specialists may not be able to understand. Moreover, it is critical to acknowledge what has already been studied and recognize the possible gaps in the thematic maps.

Another important challenge the tool must address is the standardization of data when it originates from different publications. It is very difficult to compare data created by different methodologies and for different purposes and lacking similar protocols. The data that is the standard for the SWA comes from studies developed to meet targeted goals. There is not always agreement between the collection methods and data processing in different surveys: plankton richness standardization requires consideration of how much water was filtered, macrobenthos requires consideration of how much sediment was analyzed, and so on. The same occurs with regard to standardization of rates and ecological indexes. Thus the experts also need to define how to standardize the data so it can be compared with other themes. The challenge now is to establish new protocols to collect and process data, considering each theme and the need for SDI, MSP or CWA (Carvalho *et al.,* 2012)..

Team interrelationship difficulties

Integration of knowledge focusing on biology, ecology, oceanography, engineering and sociology with management and computational areas of geotechnology is a challenge. Few specialists have been trained as managers and know little about geotecnologies. New concepts, terminology and perspectives were confronted with great difficultly since there are unskilled people, willingness to use it, or poor understanding about data management necessity.

As an incentive, the main SWA team offers training on how to build the map layers, as well as data and metadata spreadsheets that meet managers' needs.

New abilities end up being "learned on the job" and it is rewarding to observe researchers' surprise at the new insights they gain when seeing the data mapped together. As an example, seeing mangrove suppression or lost water quality as a red color on a map is much more revealing than a simple hectare measurement.

Recommendations and future research directions

Providing knowledge to improve communication that empowers stakeholders and decision-makers is essential to follow the EIA principle of sustainable development, and it is suggested that the SWA will promote this. Compared to other methodologies using data spatialization in a standardized format, such as the Oil Spill Sensitivity Maps (NOAA, 2002), the SWA model can be implemented in all global coastal zones, adopting the color standard to distinguish areas more or less impacted. SWA model language is intuitive and facilitates understanding.

However, there are still challenges to overcome. At the local level, the SWA should allow the involvement of more data from team suppliers to expand the topics already posted on the portal. Therefore, a strategy is needed to motivate researcher cooperation. An additional challenge is to standardize data from different research topics and this will be even more complex at the global level. A positive result of this effort will be using protocols for collecting and processing data for global comparison, justifying the development of training programs at the global level. According to the ICAN-IODE (2016), integration of all available local datasets is the only way to create a data and information base to support global decision-making aimed at promoting sustainability. The data repositories generated in the CWA will be valuable for providing reliable and standardized data to SDIs and MSP systems

Another aspect is to increase the amount of users' feedback to guide system improvements and resolve planning and monitoring requirements. Basically, researchers will be responsible for the quality of information and users shall ensure that the available format is the most user friendly as possible. There is an emerging scientific culture that follows this new paradigm. A broad-scale mapping concerning biodiversity is being developed in Brazil (SISBiota: http://

www.sisbiota.ufsc.br/), and there is a new consciousness about the necessity to adequate its results for decision-makers.

Another issue to overcome is funding to develop and maintain the system. This would be solved if the SWA model were adopted in EIAs as a requirement for environmental licensing or to attend to other financed demands.

5. Conclusions

Profound transformations will be necessary to achieve sustainable development and one of them is to increase access to understandable information. The SDI, MSP and CWA are ongoing efforts to improve understanding of the marine environment. But a major challenge exists in reducing the distance between academic research production and efficient management and sharing of the resulting data. According to the ICAN-IODE (2016), management and research are two widely separated worlds and data management continues to be a low priority.

This study has presented a new CWA model to promote effective management of data focused on coastal EIAs, helping to promote sustainable development. It improves the understanding of multi-criteria spatial analysis of complex ecosystems.

Moreover, it addresses the challenge of finding a common language for understanding what is occurring with regard to the state of environmental impacts in coastal zones. The tool presented offers tangible means of transferring complex knowledge from academia to a language that allows real understanding. The operational use of the systems will allow for its ongoing evolution, with the insertion of routines, functions and features to improve the processes of analysis, research, generation and dissemination of results.

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7. Key terms and definitions

Data Layers - The visual representation of a geographic theme (hidrography, land use, soil, etc.) dataset in any digital format.

Geospatial Information Systems (GIS) – a system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data.

GeoNode - a web-based application and platform for developing geospatial information systems (GIS) and deploying spatial data infrastructures (SDI).

Impacts: discrete measured changes in environmental and socio-economic values caused by human beings in comparison to the original condition.

Marine Spatial Planning (MSP): a UNESCO-IOC program to allow specialized ecosystem-based management of marine areas

Metadata - data that provides information about other data.

Open Geospatial Consortium (OGC) - an international, not for profit organization committed to defining quality open standards for the global geospatial community.

Practical Knowledge - information ownership in a systemic context

Spatial Data Infrastructure or SDI: A geoportal framework to organize the processing, use, and storage of spatial data in a geographic information system format.

Sustainable Development: the necessary harmony between human development and environmental limitations.

Web Map Service (WMS) - provides a simple HTTP interface for requesting geo-registered map images from one or more distributed geospatial databases.

Web Feature Service (WFS) - provides an interface allowing requests for geographical features across the web using platform-independent calls

Highlights

- User-friendly maps decode complex scientific data
- Interactivity promote understanding of factors that lead to impacts: cause vs effect connection

Ecological indexes are decoded as colors on maps helping environmental managers evaluation