Representation of coastal and marine environment in spatial data infrastructures to the integrated coastal zone management

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Abstract. The Brazilian government has been developing since 2008 the National Spatial Data Infrastructure (NSDI), following a growing worldwide trend to organize, catalog and manage spatial data. The main purpose of this infrastructure is to facilitate sharing and access of spatial data, optimizing the work that uses such data and reducing survey associated costs. In the context of public management, several planning areas require geospatial information, with highlight to the Integrated Coastal Zone Management (ICZM), which needs the support of both terrestrial and marine information. This paper aims to show how coastal and marine environments, particularly in the ecological aspects relevant to the ICZM, have been represented in nine selected NSDIs: Infraestrutura Nacional de Dados Espaciais (INDE) of Brazil, Sistema Nacional de Informação Geográfica (SNIG) of Portugal, Infraestructura Colombiana de Datos Espaciales (ICDE) of Colombia, Canadian Geospatial Data Infrastructure (CGDI), Australian Spatial Data Infrastructure (ASDI), Infraestructure de Datos Espaciales Española (IDEE) of Spain, Infraestructura de Datos Espaciales de la República de Cuba (IDERC) of Cuba, Sistema Nacional de Coordinación de Información Territorial (SNIT) of Chile and the National Spatial Data Infrastructure (NSDI) of United States. The comparative analysis between the Brazilian initiative and other international initiatives was made using as reference the categories of ecological information presented in the "Handbook for Measuring the Progress and Outcomes of Integrated Coastal and Ocean Management," published in 2006 by the Intergovernmental Oceanographic Commission. Almost all observed NSDIs follow the ISO19115 standard as a reference to the metadata themes, except the ICDE Colombian initiative, which differs slightly. The Portuguese SNIG and the Spanish IDEE follow the European directive named Infrastructure for Spatial Information in the European Community (INSPIRE); the CGDI Canadian initiative adopt the North Atlantic Profile (NAP) and the ASDI Australian initiative uses the metadata profile of the Australia New Zealand Land Information Council (ANZLIC). INSPIRE, NAP and ANZLIC are regional directives who adopt thematic categories in conformity with the ISO19115 standard. In Brazil, a committee subordinated to the National Cartographic Commission was formed to structure geospatial metadata. Thematic categories were included in the Brazilian INDE based on

ISO19115 standard and according to Brazilian reality. In this sense, geographic names catalogs help the standardization process and facilitate information retrieval. NSDI (EUA), CGDI (Canada) and INDE (Brazil) were initiatives that better provide access to documentation referring to NSDI, as the geospatial metadata profile or a presentation document. Considering the strategic importance of coastal and marine environments to Brazil, the publication of the present study results is expected to contribute to the development of Brazilian INDE.

Keywords: Spatial data infrastructure, geospatial metadata, Brazil

1. Introduction

The *Agenda 21*, a program of action drawn up at the United Nations Conference on Environment and Development of 1992, in its Chapter 40 – *Information for decision-making*, suggests to countries adopting a set of actions aimed to reducing differences in data and improving the availability of information (UNEP, 2012). In Agenda 21, it is recognized that information is required at all levels of decision making and that decisions are directly or indirectly related to the geographical position. The *Handbook for Measuring the Progress and Outcomes of Integrated Coastal and Ocean Management,* published by the Intergovernmental Oceanographic Commission in 2006, also highlights the importance of information in decision making related to Integrated Coastal Zone Management (ICZM), recognizing the importance of the information system in all four stages of development (IOC, 2006).

From the 1990s, recognized the importance of geoinformation in decision making and in order to facilitate their access and sharing, many countries have developed their spatial data infrastructures (SDIs), with the most diverse denominations, but with components minimally like. A broad definition of SDI is provided by Masser (2002, p.8): "policy framework, institutional arrangements, technologies, data and people that make it possible to effectively share and use geographic information". The SDIs are developed at various levels, with its own characteristics and the interrelation between these levels characterizes the hierarchical nature of infrastructure (Afonso, 2008). At country level, the SDI is called national spatial data infrastructure (NSDI). The SDI known as Global Spatial Data Infrastructure (GSDI) is maintained by the Global Spatial Data Infrastructure Association, composed of various segments of society and individuals, whose purpose is to promote international cooperation in developing SDIs at all levels.

This article aims to observe the categories listed in the profiles of geospatial metadata of nine selected SDIs, that are related to the coastal and marine environments and that are relevant for the GCI, with the ultimate goal to contribute with suggestions for the improvement of Brazilian NSDI in this regard.

2. Standards of metadata

The components of SDIs are summarized by Loenen (2006): institutional structure, financial resources, human resources, standards, technology, policies and data sets. Among these components, we highlight the standards, because they serve as a language that enables interoperability between various infrastructures. The standards facilitate the development of search engines for data and information; and possibilite the sharing of data between different actors and institutions. Both possibilities are consistent with the objectives envisaged in Agenda 21, in his chapter 40, which are: *the reduction of differences in raw data and improving the availability of information*.

According to Wilson (2009), metadata describe the origin and modifications associated with data or summarize characteristics of a data set. Referring to metadata, there are four international standards set by The International Organization for Standardization: ISO 19115:2003 (*Geographic Information - Metadata*), ISO 19115:2003 / Cor 1:2006 (*Geographic information - Metadata - Technical Corrigendum 1*), ISO / TC 211/19115-2 (*Geographic information - Metadata - Part 2: Extensions for imagery and gridded data*) and ISO / TS 19139:2007 (*Geographic information - Metadata - XML schema implementation*). The first three standards provide sections for description of metadata and the last one defines standards for implementing XML computer language of metadata.

Other standards are established for structuring metadata geospatial regional level, such as *North America Profile - NAP* (FGDC, 2007), maintained by the U.S. Federal Geographic Data Comitte (FGDC) in cooperation with Natural Resources Canada; the *ANZLIC Metadata Profile* (AS/NZS ISO 19115:2005), maintained by the Australia New Zealand Land Information Council - ANZLIC (ANZLIC, 2007); and the metadata profile of the European Directive *Infrastructure for Spatial Information in the European Community - INSPIRE* (INSPIRE, 2008).

Specifically regarding interoperability of marine metadata, the *Marine Metadata Interoperability Project - Project MMI* keeps a fairly complete list of metadata models in different fields, such as climate modeling, ecology, palaeoceanography, coastal logging and thermodynamics (MMI,

2012) . This project includes in this list the following standards: ISO19115, FGDC, ANZLIC and NAP.

Globally, the Open Geospatial Consortium (OGC) develops and maintains solutions for interoperability of geodata. The organization maintains a comprehensive list of standards for implementation, which deal with the technical specifications for implementation of SDIs and other applications for storage and processing of geodata sets (OGC, 2012). OGC is one of major components of the Global Earth Environment System of Systems – GEOSS, collaborating with other organizations in the development of the architecture of these system. The OGC also maintains other initiatives related to interoperability of geodata, being cited, related to the marine environment, the *Ocean Science Interoperability Experiment II*.

3. Encyclopedias and Thesauri

In addition to the institutional norms that standardize geospatial metadata, several controlled vocabularies and encyclopedias of specialized terms are maintained, that also help to standardizing metadata, optimizing the interoperability and the search for geodata. The National Center for Development of Coastal Data, from the National Oceanic and Atmospheric Administration - NOAA, publishes a list of such catalogs (NOAA, 2012), which may be useful to the definition of the terms that are best suited to identify and describe sets of geodata. Among others, could be cited: the *Global Change Master Directory - GCMD* (Olsen et al., 2007), the *Integrated Taxonomic Information System - ITIS*, the *Coastal and Marine Ecological Classification Standard - CMEC* and the *Geographic Names Information System - GNIS*. This latest catalog is important to the standardization of place names, information required in rules for standardization of metadata, being developed by many countries.

The *General Multilingual Environmental Thesaurus - GEMET* is a tool for indexing, retrieval and control to the center of topics and European data catalog, also serving the European Environment Agency (EEA). The tool is supported by a network of collaborators of the EEA (EIONET), consisting of approximately 1000 experts and more than 350 national institutions. The website of GEMET includes thematic, alphabetical and hierarchical lists, in addition to a list of spatial data themes that exclusively supports the INSPIRE Directive(EIONET, 2012).

4. National Spatial Data Infrastructures (NSDI)

Initially proceeded to acquire the documentation referring to geospatial metadata profile adopted by selected NSDIs: *National Spatial Data Infrastructure - INDE* (Brazil), *National Geographic Information System - SNIG* (Portugal), *Infrastructure Colombiana de Datos Espaciales - ICDE* (Colombia), *Canadian Geospatial Data Infrastructure - CGDI* (Canada), *Australian Spatial Data Infrastructure - SIDA* (Australia), *Infrastructure Espaciales Española de Datos - IDEE* (Spain), *Infrastructure Espaciales de Datos de la República de Cuba - IDERC* (Cuba), *National System of Coordinación de Información Territorial - SNIT* (Chile) and *National Spatial Data Infrastructure - NSDI* (USA).

The ecological categories present in the *Handbook for Measuring the Progress and Outcomes of Integrated Coastal and Ocean Management* (IOC, 2006), hereafter cited as *Handbook ICAM*, were used as reference for analyzing of selected initiatives:

- **E1 - Biological diversity** - *Diversity of communities, Diversity of populations, Diversity of species, Genetic diversity, Invasive species/pests;*
- **E2 - Distribution of species** - *Horizontal distribution (patchiness, aggregation), Vertical distribution (food web/trophic structure);*
- **E3 – Abundance** – *Biomass (key populations), Number of individuals (marine mammals), Density (plants, benthic organisms)*;
- **E4 – Production and reproduction** – *Primary productivity: quantity (biomass) and quality (e.g. HABs), Secondary productivity, Life history stages, Reproductive parameters, Spawning survival rates, Mean generation time (longevity)*;
- **E5 – Trophic interactions** – *Complexity of food web, Key predator/prey interactions, Keystone species, Size spectra*;
- **E6 – Mortality** – *Fishing mortality, Incidental mortalities (by-catch), Natural Mortality (predation, diseases)*;
- **E7 – Species health** – *Species at risk of extinction, (Bio)accumulation of toxic compounds, Diseases and abnormalities, Seafood quality*;
- **E8 – Water quality** – *Water column properties, Oceanographic processes and variability (and regime shifts), Sedimentation (e.g. Transport of suspended sediments), Pollutants and contaminants, Eutrophication parameter*s;

- **E9 – Habitat quality** – *Habitat types, Habitat alteration, Sea level change, Landscape and bottomscape integrity, Sediment quality (nature/properties of sediments)*;

The categories of themes of ISO19115 (MD_TopicCategoryCode class) and associated codes (ISO 2003), related to coastal and marine environments and relevant to the ICZM, are presented below:

- **Farming (001)** - *rearing of animals and/or cultivation of plants. Examples: agriculture, irrigation, aquaculture, plantations, herding, pests and diseases affecting crops and livestock*;
- **Biota (002)** - *flora and/or fauna in natural environment. Examples: wildlife, vegetation, biological sciences, ecology, wilderness, sealife, wetlands, habitat;*
- **Economy (005)** - *economic activities, conditions and employment. Examples: production, labour, revenue, commerce, industry, tourism and ecotourism, forestry, fisheries, commercial or subsistence hunting, exploration and exploitation of resources such as minerals, oil and gas;*
- **Elevation (006)** - *height above or below sea level. Examples: altitude, bathymetry, digital elevation models, slope, derived products;*
- **Environment (007)** - *environmental resources, protection and conservation. Examples: environmental pollution, waste storage and treatment, environmental impact assessment, monitoring environmental risk, nature reserves, landscape;*
- **GeoscientificInformation (008)** - *information pertaining to earth sciences. Examples: geophysical features and processes, geology, minerals, sciences dealing with the composition, structure and origin of the earth's rocks, risks of earthquakes, volcanic activity, landslides, gravity information, soils, permafrost, hydrogeology, erosion;*
- **Oceans (014)** - *features and characteristics of salt water bodies (excluding inland waters). Examples: tides, tidal waves, coastal information, reefs;*
- **Transportation (018)** - *means and aids for conveying persons and/or goods. Examples: roads, airports/airstrips, shipping routes, tunnels, nautical charts, vehicle or vessel location, aeronautical charts, railways.*

From the comparison between the two previous lists, it is observed that the ecological categories present in the *Handbook ICAM* may be behaved properly in the categories established by ISO19115. Although the examples

provided in the documentation of the standard ISO19115 are superficial, more detailed information can be organized under this outline provided.

The thematic categories set out in ISO19115 are adopted identically by most initiatives observed, except for the ICDE (Colombia). The Portuguese SNIG (IGEO, 2012) and the Spanish IDEE (CSG, 2004) follow the INSPIRE Directive (U.S., 2007); the Canadian CGDI adopts the NAP (GeoConnections, 2005) and the Australian SIDA (Australia) uses the metadata profile of ANZLIC (ANZLIC, 2007). INSPIRE, NAP and ANZLIC adopt thematic categories in accordance with ISO19115. The categories listed in the profile Colombian ICDE resemble those of ISO19115, with slight modifications.

The American NSDI adopts the *Content Standard for Digital Geospatial Metadata - CSDGM* (FGDC, 1998), now in its second version (FGDC, 2000). The NSDI is maintained by FGDC which cooperates with the Natural Resources Canada, in the development of the *North America Profile - NAP*. There are slight differences in architecture between the metadata standard of FGDC and of ISO, which can be found in the work of Prado and others (2010).

Until 2006, the United States still did not adopt in CSDGM the themes specified in ISO19115. In CSDGM, until its second version, the themes were specified according to Thesauri. The specification of the metadata category was done in the identification section of the set of geodata, comprised of subsections, among which, the subsection *Keywords* was intended to specifying keywords and topics related to geodata set. Keywords in turn, contained attributes *theme*, *place*, *Stratus* and *Time*. Since 2006, the FGDC encourages the adoption of the themes present in ISO19115, requiring the specification of at least one of these categories to identify the set of geodata (FGDC, 2006). FGDC made slight modifications in the name of the subsections of the identification section of the set of geodata (*Theme_keyword* to replace *theme*, *Place_keyword* to replace *place*; *Stratum_keyword* to replace *Stratus* and *Temporal_keyword* to replace *Temporal*). The geographical names used by the U.S. Federal Government are standardized by law and the catalog *Geographic Names Information System - GNIS* is maintained by the U.S. Board on Geographic Names (USGS, 2012b).

In Brazil, the Structuring Geospatial Metadata Committee (in portuguese: *Comitê de Estruturação de Metadados Geoespaciais - CEMG*), subordinate to the National Commission of Cartography (in portuguese: *Comissão Nacional de Cartografia - CONCAR*), included themes in Brazilian INDE according to suitability with the Brazilian reality. The list below shows the

categories related to coastal and marine environments in Brazilian INDE (CONCAR, 2009):

- **redesGeodesicas** (021) – geodesic network;
- **mapeamentoNautico** (026) – Nautical mapping, composed of bases and products of nautical charting;
- **geologiaRecursosMinerais** (036) – Marine Geology and mineral resources;
- **geomorfologia** (relevo) (037) – geomorphology;
- **monitoramentoAmbiental** (039) – Environmental monitoring, data about natural and unnatural risks, environmental indicators;
- **AreasProtegidas** (040) – Protected areas;
- **biomas** (042) – biodiversity;
- **pescaAquicultura** (045) – Fishing and Aquiculture.

The intention of CEMG was reduce redundant information since it found that more than one thematic category ISO19115 behaved in this same kind of information (CONCAR, 2009, p.126, our translation). For example, the categories *Oceans* (014) and *Transportation* (018) of the ISO19115 were condensed in the category *mapeamentoNautico* (026) (or nautical mapping), established in the geographic metadata profile (MDG) of Brazilian INDE. Although the intention of CEMG has been justified, the new categorization prejudice the specification of an important set to the ICZM, such as geodata/information regarding:

- **Pollution**, e.g. concentration of substances, indicators of contamination/pollution, habitat changes, diseases and abnormalities associated in the species, bioaccumulation of toxic compounds. It is not clear that the category *Environmental monitoring* entails data that are not collected regularly or that are associated with the health of the species/habitats or environmental degradation. One solution would be to create another category called *pollution* to behave geodata/information on this issue, leaving the category *Environmental monitoring* pose other types of geodata/information associated with the natural environment, which make up the reports of environmental quality, with data on contamination/pollution;
- **Physico-chemical characteristics of seawater**, since the term *nautical mapping* not explicitly well the nature of the category, or if the category is intended to comprise not only those data relating to navigation. In other

words, the term *marine mapping* or *Oceans* is broader than the term in question (*nautical mapping*). Maintaining the original category of ISO19115, *Oceans*, or other term which wants to use as a designation, to hold the geodata/information associated with characteristics of seawater. Maintaining the term *nautical mapping* to accommodate other geodata/information, which are relevant to navigation, whether coastal or ocean, become the structure more clear;

- **Ecology**, since reduced to two categories: *biomes*, which deals with biodiversity, and *Fauna and Flora*, which deals with scientific collections, with no chance of behaving geodata/information on species distribution, trophic interactions, abundance of species or habitat quality. One solution would be the inclusion of a category called *Ecological aspects* or *Ecology* in order to meet this need;
- **Risks**. Even though the occurrence of natural hazards in coastal and marine environment in Brazil is uncommon, begin to happen events that are recognized internationally as a result of climate change or, more strictly, excessive human pressure on the environment. Events landslides or apparent alteration of shorelines deserve to be included in an exclusive category, known as *Natural hazards* or as considered appropriate.

The strengths of the categorization included in Brazilian INDE concern the inclusion of categories intended only to protected areas and fisheries/aquaculture, important issues to the Brazilian ICZM, given the strategic importance of the maintenance of the biodiversity and the correct monitoring/management fishing resources in a country with one of the largest coastal extension.

Likewise the use of the themes, it is important to specify appropriate keywords to describe sets of geodata/information. The Brazilian Government promotes a project to draw up a list of geographic names, which will be critical to the future adequacy of Brazilian INDE and its optimization. In parallel, we can suggest the translation of the book under Global Change Master Directory - GCMD (Olsen et al., 2007) for the Portuguese in order to support the standardization of thematic keywords, since this list this catalog is extremely comprehensive. The geographic name and the theme are attributes of the MD_KeywordTypeCode class, in Brazilian INDE, and according to standard ISO19115 (CONCAR, 2009).

In general, the metadata profile of Brazilian INDE resembles those held by other NSDIs, since countries have maintained efforts to follow the ISO19115 standard. Still, some minor changes in the categorization of topics can emphasize the importance of issues related to coastal and marine environments in the country, in turn, emphasize the relevance of these

aspects contribute to the formation of a maritime mentality in Brazil, which is desirable and favorable, face to the strategic importance of coastal and marine areas and their resources for the country.

5. Conclusion

If compared with other NSDIs, the Brazilian INDE is recent, having been established by Federal Decree N.6666 of November 27, 2008 (BRAZIL, 2008). The CONCAR has effectively managed to meet the deadlines set out in the *Plan of Action of the INDE* (CONCAR, 2010), which shows the commitment of the Brazilian government and collegial with the development of Brazilian INDE. The main products generated, the *Profile of Geospatial Metadata* (MDG) and the *Technical Specifications for Structuring Digital Geospatial Vector Data* (CONCAR, 2007) are clear and well illustrated documents, compared to the SDI documentation of other countries.

From the observation of selected SDIs, it was noted that almost all follow the standard ISO19115 as to the themes of metadata, except for the Colombian ICDE initiative, which differs slightly. The initiatives that provide better access to relevant documentation are the Brazilian INDE, American NSDI and Canadian CGDI.

We also emphasize the importance of using standardized names for specification of geographic locations and themes, in order to optimize the exchange and query of geodata/information.

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