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ABYSSAL Database: an integrated WebGIS platform for deep-sea information from the South Atlantic

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Abstract

South Atlantic deep waters provide a huge diversity of habitats, with variations in areas such as geology, macrofauna, microbiology, physics, and chemistry. However, most of the data lacks central organization, important for subsequent deep-sea research, especially considering the multidisciplinary approaches and comparisons of the South Atlantic with other oceanic basins. Given the rising interest in commercial exploration off the deep-sea, especially with respect to hydrocarbon extraction and mining, there is an urgent need for a centralized repository of information with tools to collect and share geospatial data to support the conservation of this important oceanographic region. The main objective of this manuscript is to present an integrative database in WebGIS format for South Atlantic deep waters, open to further development in terms of data input, reliant on researcher collaboration, and with tools for ongoing maintenance and usability improvement driven by user feedback. The WebGIS format provides an open access, cost-free, feature-rich, and easy to use database through any Internet browser to reach the greatest number of researchers and students possible. The ABYSSAL database can be accessed at http://abyssal.io.usp.br.

Descriptors: Biodiversity, Geodatabase, Online platform, Conservation, Oceanographic data.

For many years, the deep sea was believed to be a homogenous habitat with low biodiversity (Snelgrove & Smith, 2002). Advances in deep-sea exploration revealed a diverse and heterogeneous environment in terms of both biotic and abiotic features through the discovery of several habitats (or biogeographic provinces) distributed globally across oceanic basins (Ramirez-Llodra et al., 2010, Watling et al., 2013). Nonetheless, the acquisition of knowledge of the deep sea environment is still limited to certain oceanographic basins since exploration depends on availability of resources and is thus generally restricted to developed countries or areas of commercial interest.

Deep sea areas of the Southwestern Atlantic (SWA) began to be properly explored only recently, primarily in association with oil and gas exploitation in regions of interest while others remain virtually unknown. The first scientific expedition to the SWA was the Challenger Expedition (1872-1876), conducted aboard the British HMS Challenger and one of the most important oceanographic expeditions to circumnavigate the globe, resulting in the descriptions of thousands of species new to science, from both shallow and deep waters (Manten, 1972). The deep sea of SWA would not be assessed again for almost a century, when expeditions seeking to increase knowledge

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of the Brazilian continental margin were conducted aboard the French RV Marion Dufresne (1987) and during project REVIZEE ("Assessment of the Sustainable Potential of Living Resources of the Exclusive Economic Zone", 1996-2002) (Melo et al., 2020), seeking information on living resources off the Brazilian continental margin. During the 1960s, commercial exploitation of deep sea resources in the region was just beginning, led by Brazilian oil and gas company Petrobras (Perez et al., 2020a), culminating in the development of the first offshore platform for oil extraction in deep waters (500-1600 m) in the Campos basin during the 1980s (Morais, 2013). The commercial exploration of deep sea resources also fostered scientific research on the impact of these activities on the structure and functioning of ecosystems and drew attention to ecosystem conservation and the effectiveness of regulatory and management processes that affect deep sea habitats (Perez et al., 2020a). Southeastern Atlantic (SEA) deep sea exploration is also closely linked to commercial exploitation, with the first deep water expeditions off the West African continental margin influenced by successful oil operations in the Campos basin on the Brazilian continental margin during the 1980s (Cameron & White, 1999). One of the most complete surveys of the SEA deep waters is project BIOZAIRE, which began in 1998 as a collaboration between L'Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) and industrial enterprise TOTAL. This venture sought to study different deep benthic ecosystems off the West African continental margin through a series of cruises between 2000-2005, using ROV *Victor 6000* as the primary sampling method (Sibuet & Vangriesheim, 2009).

The exploration of deep sea areas in the South Atlantic has revealed a diverse mosaic of habitats with reports of pockmarks (Sumida et al., 2004; de Mahiques et al., 2017; Ramos et al., 2020), salt diapirs (Dooley et al., 2015; Jackson et al., 2015; de Mahiques et al., 2017), carbonate mounds (Colman et al., 2005; Maly et al., 2019), cold seeps (Sibuet & Olu, 1998; Sibuet & Olu-Le Roy, 2002; Andersen et al., 2004; Giongo et al., 2016; Medina-Silva et al., 2018), asphalt seeps (Fujikura et al., 2017), ferromanganese crusts (Benites et al., 2020), ridges (Perez et al., 2020b), and organic falls, such as whale carcasses (Sumida et al., 2016).

The study of the deep sea is a multidisciplinary science involving areas of knowledge such as biology, chemistry, physics, and geology. The need to integrate data from various fields of study with a spatial reference indicates a Geographic Information System (GIS) as the ideal tool for knowledge systematization, as it is designed to cope with large amounts of data (Agrawal & Gupta, 2017). Commercial GIS software (e.g., ArcGIS) provides a variety of useful tools but is costly and requires considerable expertise (Mathiyalagan et al., 2005), limiting its usage to well-trained users and affluent institutions and thus excluding most students and researchers, especially from low- and lower-middle-income countries (LMIC). On the other hand, GIS-based tools on the World Wide Web (WWW), known as WebGIS, provide easy access at a significantly lower cost, with similar tools to access and analyze datasets and information from any device with an internet connection and a browser. The increased popularity and decreased cost of laptop computers and mobile devices have allowed widespread use of WebGIS, reinforced by initiatives from developers and user communities and supported by the creation of several WebGIS architectures (Agrawal & Gupta, 2017). Painho et al. (2001) defines WebGis as "[...] a complex system with access to the internet for capturing, storing, integrating, manipulating, analyzing, and displaying data related to locations without the need of having proprietary GIS software".

The aim of the present work is to present the "Assessment of the Deep Benthic Ecosystems of the Southern Hemisphere Atlantic Sector" (ABYSSAL), an open-access database in WebGIS designed and developed to gather, curate, and allow free access to multidisciplinary data on the South Atlantic deep sea. The primary goal of this database was to create a free and easy online archive for interested researchers and students to both deposit and access deep sea information associated with multiple tools. Hereby, we describe the architecture and design and demonstrate the tools available and applications for both contributors and users.

The ABYSSAL database was developed as part of the project “Biology and Geochemistry of Oil and Gas Seepages, SW Atlantic” (BiOil), funded by Shell Brasil Petróleo LTDA and coordinated by the Laboratório de Ecologia e Evolução de Mar Profundo (LAMP) of the Instituto Oceanográfico from the Universidade de São Paulo (IO-USP).

The architecture of the WebGIS consists of a three-layer application system (Figure 1). The data layer that stores all information is composed of a MySQL spatial database and files used to support research uploaded by partner researchers. These include data tables in .xlsx format with information of macrofauna reports, ROV footage in .mov or .mp4 formats, and geophysical surveys (e.g. multibeam echosounder) in GeoTIFF (georeferenced .tiff file) format. In all cases these provide geospatial information including latitude, longitude, depth, and physicochemical information of the sampling site (e.g. salinity and sediment type), when available. Data importation features automated quality control that flags errors and inconsistencies in the data, such as incorrect format or corrupted files. After uploading, new data is validated by a researcher associated with ABYSSAL to filter other error types undetected by the automated routine.

Data is stored on a DL380 server located at the IO-USP, with two Intel Xeon Silver 4114 processors, 128 Gb of RAM, and 126 TB of storage across sixteen hard disks in a RAID 6 array. The server also handles the application layer, developed in Python using the Django framework, and the open-source libraries NumPy and SciPy. The presentation layer is the graphical user interface through a web browser and is built in HTML, Cascading Style Sheets (CSS), and TypeScript transpiled into JavaScript, using opensource libraries Openlayers, Highcharts, and JQuery.

ABYSSAL (http://abyssal.io.usp.br) is the first online geodatabase of deep sea information for the South Atlantic Ocean encompassing biological, microbiological, geological, chemical, and physical data in a multidisciplinary repository. Registration and login are required to access the database and map tools. Database tools include data filtering that enable search and categorization of specific subjects, as well as mapping tools that allow users to create, edit, visualize, and download desired maps and data or convert important information into graphics and tables using any combination of available datasets, granting customization potential in any research area.

The mapping tools of ABYSSAL WebGIS allow the visualization of the desired data directly on the map and filtered by layers through selection tools categorized by area of interest, such as microbial

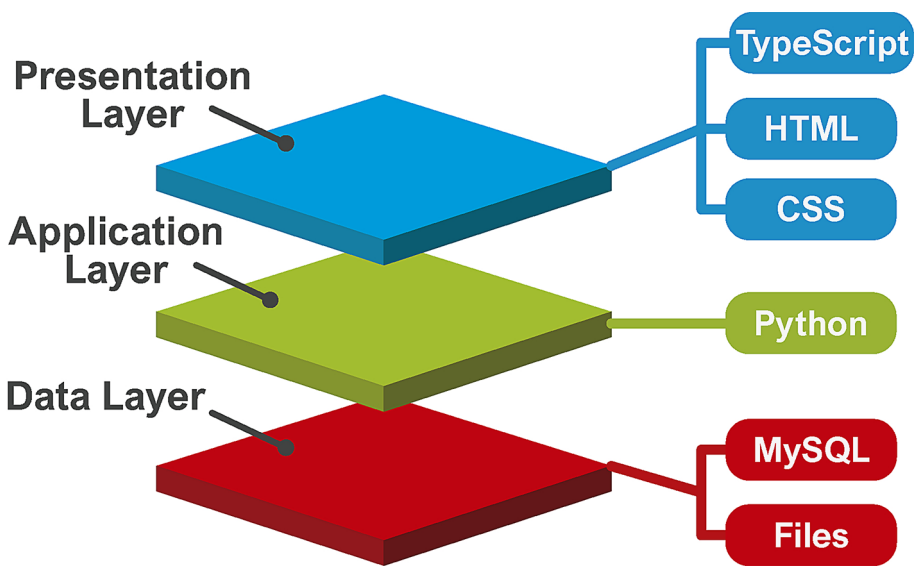

Figure 1. The three layers architecture of the ABYSSAL WebGIS including composition of each layer.

process, macrofauna, environmental, and geophysical data and ROV tracks (Figure 2). The user can filter which data is displayed by selecting map layers, thus filtering the data according to sampling type or constraining it to a region of interest (Figure 2). Additionally, there is a search tool for the benthic macrofauna from any taxonomic hierarchy which returns the organism distribution as bubble plot representing relative abundance (number of individuals) of the selected taxon on the map. Users are also able to search by other parameters such as depth, project, latitude, longitude, and others, as well as delimit an area of interest with free-drawing polygons, and measure distance on the map (Figure 2).

Data of interest can be directly downloaded from the mapping tool page, including map downloads in various image formats (e.g. .png, .tiff, etc.) maintaining selected layers and applied tools, as well as raw data as worksheets in both .csv and .xlsx formats.

The database relies on collaboration for data acquisition. As such, researchers may register on the website to become partners of ABYSSAL and, upon administrator approval, upload new data to contribute to South Atlantic deep sea knowledge. Uploaded data would be incorporated into the database with important information such as hierarchic taxonomy identities, methane, n-Alkanes, hopanes and polycyclic concentrations, and microbial chemosynthetic rates, etc., and all graphics are automatically generated. Other types of data can be uploaded, such as videos (e.g. from ROV surveys) or images (e.g. pictures of box-corer samples). All steps for data upload are described in the ABYSSAL database website.

The importance of global repositories of biogeographic datasets such as the Ocean Biogeographic Information System (OBIS) and Global Biodiversity Information Facility (GBIF) is unquestionable (Costello & Chaudhary, 2017; Howell et al., 2021). The ABYSSAL database development was influenced by both repositories but is not limited to biological and biogeographical data. ABYSSAL is limited to deep sea data and information, which allows the database to focus and specialize in supporting data from various fields of study concerning this environment, including physical, chemical, geological, microbiological, and faunal. The database is also focused on the South Atlantic Ocean, facilitating management and encouraging researchers to deposit their data for this poorly known region.

The multidisciplinary nature of the deep sea data represented a great challenge in developing

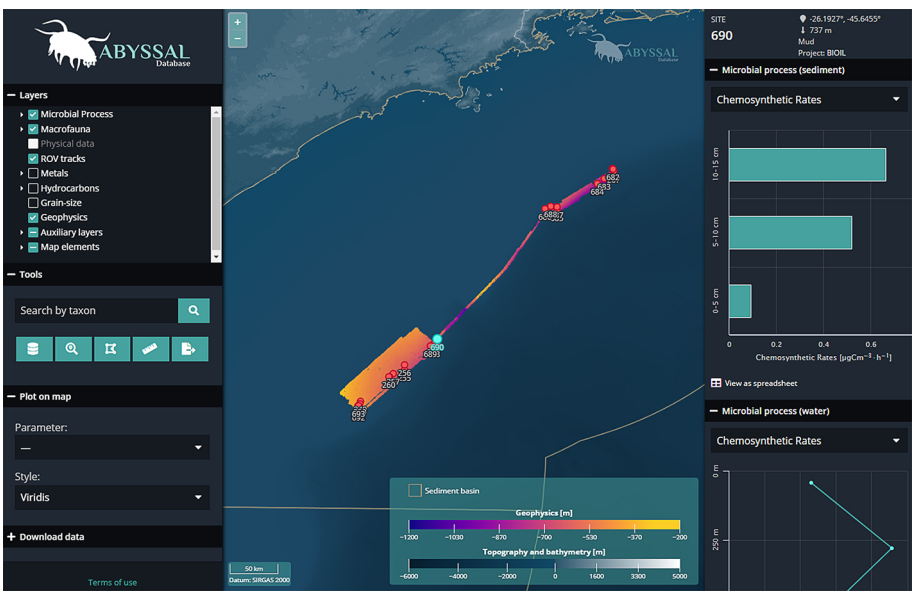

Figure 2. Example of a section of the mapping tool from ABYSSAL database website, including customizable layers and tools at the left corner, an example map of the sampling areas of the project BiOil at the Santos Basin (SWA) at the center and data visualization at the right corner.

a website that can house and manage access to a complete database used and supported by researchers from all areas of study in a collaborative manner. Another challenge was selecting a server to support a large database and new data from future studies. The main objective of this project is to create a long-lasting integrated database platform with all possible information from the deep waters of the South Atlantic Ocean. This was overcome with the opportunity to host the ABYSSAL database on a high-end server at IO-USP, allowing for the input of large data sets as well as providing sufficient computational power to process the application layer tasks. The server storage can also be upgraded in future and is located in the same facility as the LAMP, facilitating maintenance and longevity.

The first data entries were from Brazilian projects led by IO-USP, including the BiOil project, from which the database originated. However, the inclusion of data from other projects and research groups from other institutions and countries is strongly encouraged. This manuscript is an invitation to any organization that acquires or analyzes data from the South Atlantic deep sea, since partnership, support, and group work are key to greater scientific achievement. The aim is to create a flexible and evolving platform, not only with respect to data contribution but also in relation to available tools; developers will constantly update WebGIS based on user feedback. The project website offers a contact section for feedback and for users to report problems and bugs.

Databases are an important tool for conservation and environmental monitoring, especially in open, web-based formats that provide information in accessible forms, as opposed to conservation practices based on anecdotes and myths that hamper the work of practitioners (Sutherland et al., 2004). Diminishing mineral reserves in shallow waters is pushing the exploration of hydrocarbons and the mining of metals such as Mn, Co, Ni and Cu (Glasby, 2000) into the deep sea (Davies et al., 2007). The ABYSSAL database can provide information for environmental monitoring of the deep sea to support conservation through a diversity of knowledge areas such as fauna, physical and chemical variables, and geological features.

All data available at the ABYSSAL database can be used for research purposes and manuscript productions. We hope the database contributes to the dissemination of the knowledge of South Atlantic deep sea and to research throughout the world by making the deep sea data more accessible.

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AUTHOR CONTRIBUTIONS

G.B.: Conceptualization; Validation; Writing – original draft; Writing – review & editing.

O.C., B.H.M.S., T.N.S.B., P.D.N.: Conceptualization; Validation; Writing – review & editing.

P.V.F.C., A.Z.G.: Validation; Writing – review & editing.

P.Y.G.S.: Funding acquisition; Resources; Supervision; Conceptualization; Validation; Writing – review & editing.

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