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Island-based Information Management System-GIS Data Centre as a key tool for spatial planning in the South Atlantic UK Overseas Territories

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ABSTRACT: Environmental data require fit-for-purpose data management systems and related spatial applications to be used effectively for management. Geographic Information Systems (GIS) have become a key tool to analyse and visualise spatial data with their increasing volume and variety. Well-designed data centres that combine a data management system with GIS, reduce costs and improve efficiency for spatial planning processes. Small or remote territories and islands such as the South Atlantic UK Overseas Territories (SAUKOT), with limited financial resources and capacity, face many challenges to develop such centres. In 2013 an island-based Information Management System (IMS)-GIS Data Centre was established in the SAUKOT. Until then, governments did not have the ability to use spatial planning effectively to manage their environments. The IMS-GIS Data Centre has been operating as: 1) repository of high-quality reference datasets to support decision making, 2) interactive data visualisation to share maps and information with stakeholders and 3) data portals to assist data discovery and sharing. This paper describes i) how the SAUKOT have built their own IMS-GIS Data Centres ii), how these Data Centres have provided effective and manageable solutions to support terrestrial and marine spatial planning processes and iii) the challenges the Data Centres are still facing. Thanks to relatively simple data management concepts and the use of open-source programs, the IMS-GIS Data Centre is transferable to other contexts sharing similar challenges to those faced by the SAUKOT.

Keywords: Data management system, data centre, GIS, spatial planning, open-source, remote islands.

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RESUMO: Os dados ambientais exigem uma adequação dos sistemas de gestão de dados e respetivas aplicações geográficas para que sejam utilizados eficazmente na gestão. Os Sistemas de Informação Geográfica (SIG) tornaram-se uma ferramenta essencial para analisar e visualizar dados espaciais com seu volume e variedade crescentes. Os Data centers bem projetados, que combinam um sistema de gestão de dados com SIG, reduzem custos e melhoram a eficiência dos processos de planeamento espacial. Os territórios e ilhas pequenas ou remotas, como os Territórios Ultramarinos do Atlântico Sul do Reino Unido (SAUKOT), com recursos e capacidade financeira limitados, enfrentam muitos desafios para desenvolver esses centros. Em 2013, um centro de dados do Sistema de Gestão de Informações em Ilhas (IMS) foi estabelecido no SAUKOT. Até então, os governos não tinham a capacidade de usar o planeamento espacial efetivamente para gerir os seus ambientes. O IMS-GIS Data Center opera como: 1) repositório de conjuntos de dados de referência de alta qualidade para apoiar a tomada de decisão, 2) visualização interativa de dados para compartilhar mapas e informações com as partes interessadas e 3) portais de dados para auxiliar na descoberta e compartilhamento de dados. Este artigo descreve i) como os SAUKOT construíram os seus próprios Data Centers IMS-GIS; ii) como esses Data Centers forneceram soluções eficazes e geríveis para apoiar os processos de planeamento espacial terrestre e marinho; e iii) os desafios que os Data Centers ainda enfrentam. Graças a conceitos de gestão de dados relativamente simples e o uso de programas de código aberto, o IMS-GIS Data Center é transferível para outros contextos que compartilham desafios semelhantes aos enfrentados pelo SAUKOT.

Palavras-chave: Sistema de gestão de dados, data center, GIS, planeamento espacial, código aberto, ilhas remotas.

1. INTRODUCTION

Spatial data are data that can be visualised on a map because they are linked to a site or a particular location with the use of geographical coordinates based, most often, on latitude and longitude. Geographic Information Systems (GIS) are well-established computer-based tools for spatial data manipulation, analysis and visualisation that are now extensively included in environmental spatial planning and policy-making (O'Shea, 2006).

Spatial planning is a strategic and integrated process that spatially allocates different human-use functions and activities across a landscape as efficiently and effectively as possible to maximise the benefits and ensure environmental sustainability in the long-term. The process initially requires spatial data on abiotic (*e.g.* Geology, Climatology, Hydrology) and biotic (*e.g.* flora, fauna) ecosystem components and on human activities (*e.g.* land use, shipping traffic) and values (*e.g.* economic, cultural) (Wit *et al.*, 2009). These data first allow spatial planners to identify and describe the environmental and socio-economic context that affects the communities and their environment. This information can then be used during the planning and policy-making process for understanding the spatial context in which people and nature coexist and for defining the allocation of space that balances the value of people and nature, to ensure sustainable development and environmental integrity of ecosystems (Wit *et al.*, 2009). Geo-processing functions such as map overlay, connectivity measurement, cost/benefit evaluation, suitability assessment, buffering (Longley *et al.*, 2010), photogrammetry from UAV surveys (Scarelli *et al.*, 2016 ane Scarelli *et al.*, 2017) and interactive mapping (webGIS) are some of the GIS analytical and mapping tools used by spatial planners. Thus, spatial planning processes and GIS are interlinked from the initial definition and analysis of the present situation and stakeholder engagement, to the final mapping of possible future scenarios and decision making. However, the best spatial data and GIS functionalities are not sufficient to enhance the workflow of the spatial planning process for achieving efficiency in its performance and application.

The spatial planning process needs a long-term data management system that provides continuous and structured data management and that takes care of how data are collected, documented, analysed, publicised, stored and ultimately archived (Zwirowicz-Rutkowska and Michalik, 2016; USGS, 2018). For example, without a data management system in place, data sources can be disparate and data availability remains uncertain. The time and resources needed by the spatial planners to compile and map the data can also be significantly longer, even if data have been used in the past for a different process or planning. The spatial planning process becomes expensive and it slows down with a negative impact on keeping the scheduled deliverables on time and the quality of the planning outcomes acceptable. Furthermore, if spatial planners do not have a clear knowledge of who, when and how data have been generated because an accurate documentation is absent, the risk of introducing low quality data in the analytical process increases. From a spatial planner perspective, saving time in collecting and collating spatially-explicitly data results in speeding up the initial phase of the spatial planning process. Similarly, having access to official, documented and referenced datasets ensures reliable outcomes at its end.

The data management system also needs to support standard best practices for data collection and policies including plans for data security and the protection of copyright and intellectual property rights. This offers credibility and reliability to those who provide or own data that are used in planning processes. As a result, the likelihood that data are delivered according to standards shared or made more accessible to spatial planners and other potential data users increases.

A data management system does not stand in isolation. It requires the presence of a data centre and a dedicated data manager or a team of data managers depending on its scale. All around the world, there are organisations, institutions and data centres that look at finding solutions that satisfy the requests of services that facilitate data discovery, access, manipulation, analyses and visualisation. Online data portals, data repositories, metadata catalogues online, and web mapping platforms are designed and built to allow data users to easily source data, verify their quality and validity, and disseminate information. For example, BirdLife International (http://www.seabirdtracking.org/mapper/index.php) and Movebank (https://www.movebank.org/) provide the infrastructure and the data managers to maintain and manage some of the largest databases on animal tracking data. Similarly, the London-based Natural History Museum (NHM) (http://data.nhm.ac.uk/) and Kew Gardens (https://www.kew.org/science/data-and-resources/data) make available more than 80 million specimens from one of the world's most important natural history and plant/fungal collections. The UK Polar Data Centre (https://www.bas.ac.uk/data/uk-pdc/) managed by the British Antarctic Survey (BAS) is the focal point for Arctic and Antarctic environmental data management in the UK. This data centre offers services to explore and discover the data, but also support researchers in complying with national and international data legislation and policies.

The organisations and institutions given as examples of data centres with *ad hoc* data management systems have the human and financial resources to sustain the management of data coming in large volume and frequency and various formats. However, in remote islands and territories, spatial planners and data managers face several challenges due to the physical isolation (Figure 1 and Table 1), the lack of existing data policies, the access to basic information technology, the financial constraints and the narrow pool of skills and technical expertise in spatial analytical tools.

Here, we show how the development of the Information Management System-GIS (IMS-GIS) Data Centre in the South Atlantic UK Overseas Territories (SAUKOT) has taken place and how challenges were overcome. This paper describes 1) how the SAUKOT have built their own data management system under the standards provided by the IMS-GIS Data Centre 2) how these Data Centres have provided effective and manageable solutions to support terrestrial and marine spatial planning processes and 3) the challenges the Data Centres are facing.

2. THE ROLE OF THE IMS-GIS DATA CENTRE AS SUPPORT TOOL FOR SPATIAL PLANNING PROCESSES

The SAUKOT are a set of remote islands found from the equator down to the Antarctic (Figure 2). Due to their remoteness, marine and terrestrial ecosystems are unique and comprise of many endemic species that are irreplaceable and valuable assets not only for the islands (FIG-EPD, 2016; Otley *et al.*, 2008; SHG-EMD, 2012; Taylor *et al.*, 2016) but also for the UK, since it has been estimated that approximately 90% of the UK's biodiversity resides in the overseas territories (Wentworth, 2013). The islands have their own governments that oversee the management of the marine and terrestrial areas.

Research grants and conservation programmes provided by the Foreign Commonwealth Office (FCO), the UK Department for Environment, Food and Rural Affairs (The Darwin Initiative and the Darwin Plus grant schemes), the UK Department for International Development (DFID) or the European Union (*e.g.*, EU BEST programs) have assisted the local governments to sustain the effort and the costs of data collection. However, these types of funding had never included support for the establishment of island-based Data Centres where governmental data management systems and plans could ensure the availability of data for spatial planning and decision-making processes for the islands.

Without direct governmental control over the collected data from the islands and their marine areas, poor data documentation and taking data back to overseas academic institutions without providing copies to local government became widespread habits among the researchers and data collectors working in the islands. As a consequence, data were lost, and others were duplicated in the attempt of recovering the data that went missed. Overall, the work of local spatial planners, conservation Non-Governmental Organisations (NGOs) and government officers was affected as the accessibility to the data was compromised. Time, effort and resources instead of being invested in understanding and learning something new about the local environment, were targeted to fill gaps and chase datasets around the world due to the lack of a functioning data management.

In order to remedy the lack of data management in the SAUKOT, in late 2013, the Foreign Commonwealth

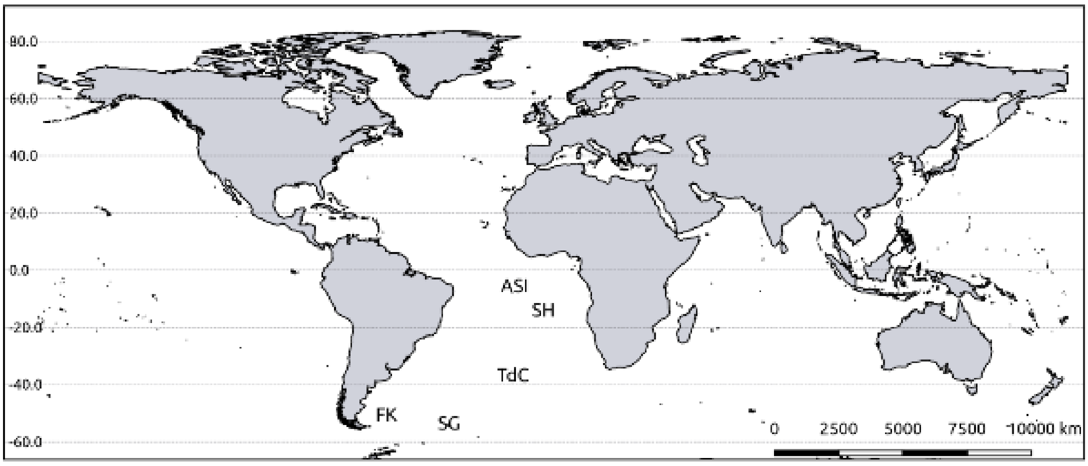

Figure 1. Locations of the South Atlantic UK Overseas Territories: Ascension Island (ASI), Saint Helena (SH), Tristan da Cunha (TdC), Falkland Islands (FK), South Georgia (SG). Datasource: https://www.naturalearthdata.com/downloads/50m-physical-vectors/

Table 1. The table describes the remoteness of the territories by providing journey time, type and frequency of connection (update 2018) from each territory to the main overseas land. It is worth noting that for Tristan, due to the reduced number of berths in the vessel, the priority is given to islanders. For South Georgia, the vessel main function is patrolling the Maritime Zone from illegal fishing practices and it is used to provide access to the island to the Government officers and their family.

Territory	Transport	Number of connections	Time
Falkland Islands	plane	3 flights/Wk.	18 hrs from the UK 1.5 hrs from Punta Arenas
Saint Helena	plane	1 flight/Wk. 2 flights/Wk. (Dec-Apr)	6 hrs from Johannesburg
Ascension Island	plane	1 flight/m. to Saint Helena	1.5 hrs from Saint Helena
Tristan da Cunha	vessel	10 ships/Yrs. (max 12 passengers)	5-8 d. (weather dependent) from Cape Town
South Georgia	vessel	Sporadic governmental vessel (max 12 berths); Cruise ships in summer	2-6 d. (weather dependent) from Stanley-Falkland Islands

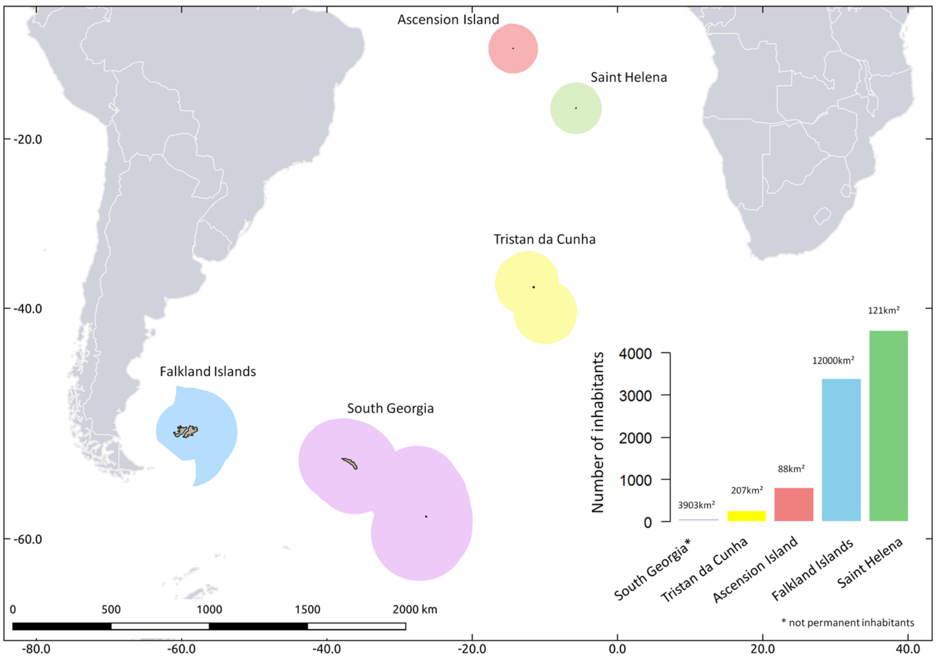

Figure 2. Areas managed by the South Atlantic UK Overseas Territories, including their Exclusive Economic Zones (EEZ) and histogram of the number of inhabitants with the land area (in km²) indicated above each bar(right down corner).
Datasource: https://www.naturalearthdata.com/downloads/50m-physical-vectors/

Office, via the Joint Nature Conservation Committee (JNCC), sponsored the development of the IMS-GIS Data Centre in the Falkland Islands and Saint Helena (https://www.south-atlantic-research.org/research/data-science/). The management and oversight of the project was given to the JNCC (JNCC, 2016), whereas the newly-born South Atlantic Environmental Research Institute (SAERI) created in 2012, based in the Falkland Islands, had the responsibility of designing the architecture of the island-based central data repository for the environmental data collected in each SAUKOT (South Georgia and the South Sandwich Islands were not included as their Government contract British Antarctic Survey to do their data management). During the two-year project, SAERI's main tasks were to develop and implement tools for a long term, sustainable and practical data management system. Initially two GIS specialists and data manager posts were created in the Falkland Islands (2013) and in Saint Helena (2014), followed up by a part-time data manager post in Ascension Island (2015). On island data managers were fundamental to the efficiency and success of the South Atlantic wide IMS-GIS Data Centre.

One of the advantages of starting a data centre from scratch was the opportunity to create an architecture that fits the geographical and socio-economic characteristics of the SAUKOT, and that accommodates the ambitions and requirements of its users on the islands. Another advantage of starting a new process was the abundance of models and best practices that could be used as a guide during the design and development phase. Thus, the IMS-GIS Data Centre was created through a participatory, open and inclusive process, where local stakeholders, ranging from government offices and representatives of local and international NGOs, and overseas researchers helped prioritising the data services and identifying where international standards (AGI, 2012) and existing data policies (NERC, 2018; Van den Eynden *et al.*, 2011) needed simplified and turned into tools for data management.

The main objective of the IMS-GIS Data Centre was to provide the small territories with a data management system that would be standard across the territories, and could be understood by the users and maintained locally in the long term. A system architecture that could take into consideration these points was designed and implemented (Figure 3). Open-access software was used for all components of the system (QGIS, 2018; PostgreSQL, 2018; PostGIS, 2018).

A simple searchable online catalogue was designed as first solution for the retrieval of the metadata harvested by the IMS-GIS Data Centre in the various SAUKOT. Many metadata had their corresponding data stored locally on dedicated servers and the data were made accessible to data requestor via a data request form (https://www.south-atlantic-research.org/research/data-science/data-services-metadata-catalogue/). This elementary system has been upgraded between 2018 and 2019 thanks to a collaboration with the Satellite Receiving Station at the University of Dundee. A more complex data portal based on CKAN (https://ckan.org/) was built only for the Falkland Islands Government. The improved data service has the main advantage to discover metadata and data with the same online search. If the data are classified as "open access", then the resource can be downloaded directly from the portal. Otherwise, the data requestor has to fill an online form and receive the authorisation for the data download via email (http://dataportal.saeri.org).

Although the IMS-GIS data centre system architecture reflects the standard life cycle of data, it was revolutionary for the SAUKOT, because it introduced concepts new to the majority of the stakeholders and kept the tools used for its implementation simple (*e.g.*, an excel file for the metadata form and a word document for the data request, in the case of the former metadata catalogue) and without a licence fee. Furthermore, the change of habit requested by the data management system was fully supported by free training courses on how to use and apply GIS, how to fill in metadata records, and assisted by guidelines and explanations on why data curation impacts on spatial planning and decision-making processes. Aims, objectives and solutions identified for the realisation of the IMS-GIS Data Centre reflect the attention dedicated to the end-users and the intention of delivering a practical and sustainable data management system (Table 2). A series of case studies are presented to describe how and in which terms the solution proposed by the IMS-GIS Data Centre became practical and useful services for spatial planners and how the existence of the IMS-GIS Data Centre impacted positively on small islands spatial planning processes.

3. CASE STUDIES

3.1 Marine Spatial Planning for the Falkland Islands

In 2014, at the same time as the IMS-GIS Data Centre was being developed, the Falkland Islands Government with the UK Government support (via the Darwin Plus Programme) started a project to initiate Marine Spatial Planning (MSP) (https://www.south-atlantic-research.org/research/completed-research-projects/marine-spatial-planning-for-the-falkland-islands/). One of the goals of this project was to gather data relevant for spatial planning (environmental, anthropogenic and biological)

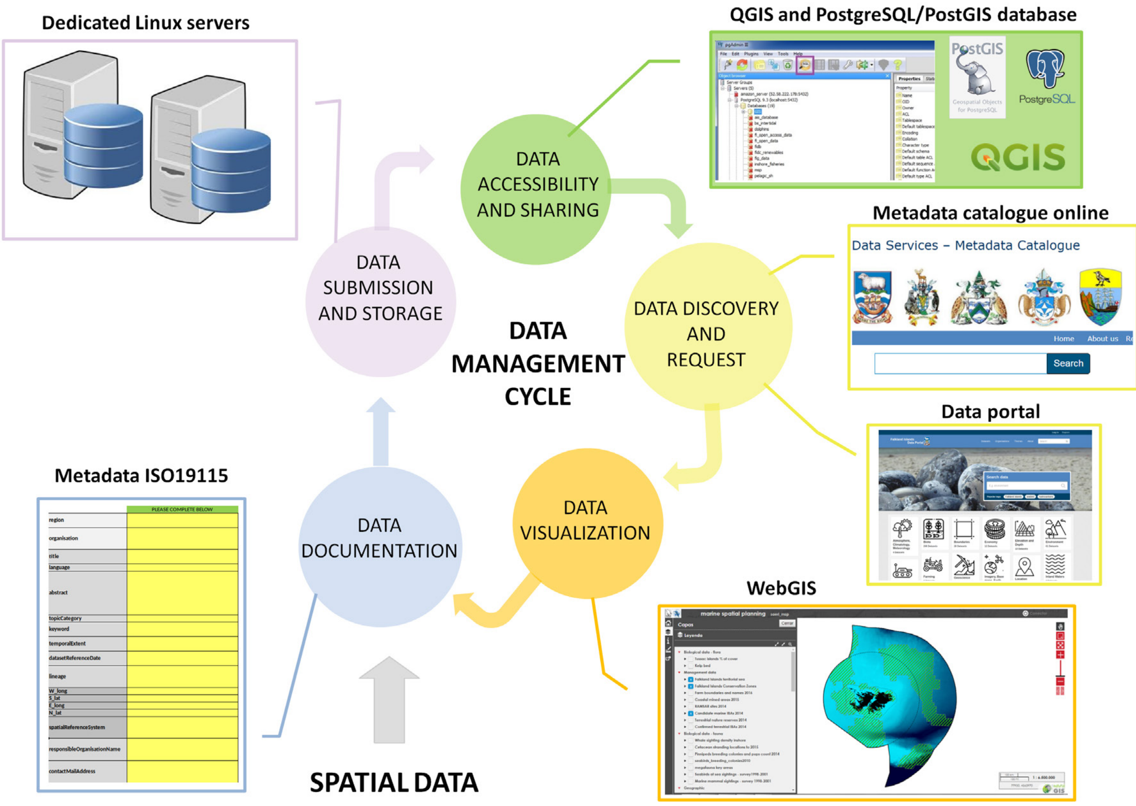

Figure 3. System architecture of the South Atlantic UK Overseas Territories Information Management System-GIS Data Centre. For each phase, the main component and type of service provided are highlighted.

Table 2. Summary of the aims, objectives, and solutions identified and implemented by the IMS-GIS Data Centre in its years of activity (2013-2019).

AIMS	OBJECTIVES	SOLUTIONS
Design a simple and manageable metadata harvesting process that would ensure data documentation	Adopt a metadata standard form. Include the metadata form as part of the Research Permit Application. Meet overseas researchers either before or after data collection. Provide training and explanation on how to fill the metadata form correctly. Collect metadata at short distance from data collection. Include metadata into the metadata catalogue Publish metadata regularly	Metadata catalogue online for SAUKOT except the Falkland Islands https://www.south-atlantic-research.org/research/data-science/data-services-metadata-catalogue/ CKAN-based Data portal for the Falkland Islands http://dataportal.saeri.org
Ensure that a copy of the data collected by overseas researchers is also kept and stored in a server on the island	Invest in hardware. Set up two secure servers: one acting as a data bank and the other working as an off-site back-up. Ensure the level of security for both servers	Central data repository based on the island
Allow as many people as possible to familiarise with and learn how to use analytical and mapping tools such as GIS	Organise training courses in GIS and data management to cover basic, intermediate and advanced level. Adopt QGIS as a GIS tool. Adopt PostgreSQL and PostGIS as spatial database	Embrace open source movement and use open source software https://www.south-atlantic-research.org/news/
Consolidate data management and use of standards among data owners and users	Engage with local stakeholders to identify solutions that can fit with the islands. Do not reinvent the wheel, but take data policies from other countries as models and re-frame them to reflect stakeholders inputs. Design a data management system that is simple, manageable and sustainable in the long term	Publications, through a dedicated web portal, of local data polices and standard guideline for best practice in data management https://www.south-atlantic-research.org/research/data-science/guidelines-and-data-policies/
Facilitate access to data and information within the islands and between the islands and the rest of the world	Work with governmental IT and telecommunication provider to ensure that locals can access the services at minimum cost. Adopt interoperability schema for ensuring data sharing within the island. Design, develop and implement webGIS and other web application to make data and information widely accessible	System based on interoperability. webGIS projects https://www.south-atlantic-research.org/research/data-science/managing-data/webgis-projects/

to understand where issues already existed, to identify key knowledge gaps and for analysing tracking and sighting data and identify key areas for marine megafauna (Augé *et al.*, 2018b). Another goal of the project was to start educating and engaging stakeholders and the local community in MSP so they would understand the benefits of the process.

The IMS-GIS Data Centre provided some initial baseline spatial data and then was used as the repository for all the data gathered or created during the project so that any further projects and spatial planning analyses would benefit from the effort put in gathering that data. In total, 35 datasets were added to the IMS-GIS Data Centre metadata catalogue during the project. Data ranged from existing data that were available but not catalogued publicly (*e.g.*, fisheries management areas), data that were digitised and formatted as part of the project (*e.g.*, cetacean stranding data, Augé *et al.*, 2018a), to new data created during the project from research (*e.g.*, cultural coastal values, Blake *et al.*, 2017).

The IMS-GIS Data Centre also allowed storing and recording raw data, not directly useful for MSP, but that was used for analyses that provided the layers required for spatial planning. For instance, a study part of the MSP project gathered all available information on historical whale sightings in the Falkland Islands to understand better their status and current distribution to feed into spatial planning (Frans and Augé, 2018). Many raw data were acquired and digitised (*e.g.*, local ecological knowledge, commercial whaling catch data). While the data relevant for marine spatial planning was the output layer of this study (*i.e.*, distribution of whales), the raw data were essential and needed to be recorded and stored because they could be used for further studies, in particular as the study was published and future researchers may want to analyse the data when new data become available in the future. The IMS-GIS Data Centre was essential in the ability to store these data and make it available for future studies.

The GIS training courses promoted by the IMS-GIS Data Centre and the adoption of open source GIS and spatial database solutions allowed for a successful collaboration to make the data collected and derived through the MSP project available to stakeholders, independently of their GIS skills. If in the past, a single licence use of GIS software determined that only one person could be in charge of analysing and mapping spatial data, the use of licence-free tools, gave many people the opportunity to learn new skills. Free spatial database solutions facilitated data sharing across data users within and between organisations. For instance, data from the MSP process were accessed and viewed by GIS users at various government departments and research institutions locally and overseas. Where learning and understanding GIS was not a necessity and priority, webGIS services came to a hand as useful tools for understanding the value of spatial planning. The wider public and the majority of stakeholders could access and visualise the MSP data from a dedicated webGIS (https://data.saeri.org/saeri_webgis/lizmap/www/index.php/view/map/?repository=04f&project=webGIS20170717). The webGIS provided by the IMS-GIS Data Centre was a key element of successful stakeholder engagement and they repeatedly expressed how useful this tool was for them to be able to understand the value of MSP, and for consultation. The webGIS was also useful for running workshops and public meetings.

3.2 Spatial Planning for the Common of Stanley, Falkland Islands

In 2018, a web-based public participation GIS (PPGIS) approach together with the integration of spatial data from the IMS-GIS Data Centre was used by the Falkland Islands Government (FIG) to support the creation of a management plan for the public area known as Stanley Common. The area was prone to usage conflicts arising from a large variety of stakeholders and stakeholder interests. The use of PPGIS to identify activity use as well as data gathered on artefacts, infrastructure, and natural features was facilitated by the data repository provided by the IMS-GIS Data Centre. The IMS-GIS Data Centre served as an easy-to-use tool to quickly gather all the relevant spatial data available for the area known as Stanley Common. This included spatial data on public infrastructure as well as natural features. Where in some instances the data were not yet in the Data Centre, they were gathered and were entered in the Data Centre and its metadata catalogue for later analyses, policy making, research studies and for avoiding repetition of effort in the future. The use of spatial data facilitated mapping conflicts and enabled practitioners to better understand where management efforts can help achieve resolution and clarity.

3.3 Management of environmental research permits in the Falkland Islands

Research permits issued by the FIG are required by anyone undertaking environmental research in the Falkland Islands. These permits allow FIG to document the on-going environmental research in the Falkland Islands and establish where new sources of data are created. The IMS-GIS Data Centre data manager worked with the environmental officer to create a data management policy for the Data Centre and to ensure that permit applications now include a close where researchers must provide a copy of their raw data to FIG via the Data Centre metadata catalogue. Data are stored in the Data Centre and can be used for environmental management decision purposes of the islands (with appropriate acknowledgements). This metadata is available through the centre where it can be used to inform on data available and data ownership and access. It became a key tool for researchers intending to undertake research in the Falkland Islands as they can identify the data gaps or where research activities would be a duplication of effort. The Centre has also developed guidelines for data management and permit applications for researchers with a "checklist before arriving in the Falklands" (https://www.south-atlantic-research.org/research/data-science/check-list-before-arriving-to-the-falklands/). It also enables researchers to synergise their efforts where research overlaps exist.

3.4 Mapping Natural Capital in the SAUKOT

The UK Government, through the FCO managed Conflict, Stability and Security Fund (CSSF), is supporting a suite of natural capital projects across the UK's South Atlantic and Caribbean Overseas Territories. This work is designed to improve economic stability in the Territories through enhanced environmental resilience as part of a programme led by the UK's Department for Environment and Rural Affairs (Defra). The natural capital project began in September 2016 and will be completed by March 2019 with the JNCC as the Implementing Body. In the South Atlantic, the natural capital project work is being undertaken by SAERI under a Memorandum of Agreement with the JNCC (https://www.south-atlantic-research.org/research/terrestrial-science/natural-capital-assessment/).

This project assists the territories in assessing and mapping natural capital, valued priority assets, and deploys decisions support tools to secure long-term economic benefits from the sustainable management of their natural assets. The outcome will be a framework for the SAUKOT to assess the value of the environmental goods and services available and integrate this information into marine and terrestrial spatial planning, economic planning and environmental protection. The natural capital project focuses on:

- mapping spatial data on the distribution of selected natural capital assets, both marine and terrestrial, derived from satellite imagery and other existing resources, as relevant to each Territory;
- valuating of priority natural capital assets (value mapping integrated into national GIS) and assessing the economic and societal benefits arising from them;
- applying analytical tools that will support decision making in the context of environmental management and economic development (*e.g.*, scenarios); and
- identifying methods for monitoring changes to priority natural capital over time using appropriate attributes (*e.g.*, indicators).

To achieve the deliverables, the project utilises extensively the IMS-GIS Data Centre's metadata catalogue online and open source GIS tools for the development and collation of spatial evidence, and the technical expertise of the local data managers for promoting knowledge exchange and capacity building within the territories in the region.

For instance, in Saint Helena, the project supported a cost-benefit analysis (CBA) to explore different waste management options for the island, including improved recycling to extend the life of the existing landfill site. One option within the CBA included developing a new landfill site, and identifying a suitable site was part of the analysis. With flat land at an absolute premium on the island, identifying suitable locations was going to be a challenge. The use of GIS spatial analytical techniques proved an ideal solution (Marengo *et al.*, 2018). The recently completed Darwin Plus project 'Mapping St Helena's Biodiversity and Natural Environment' (Pike *et al.*, 2018), provided the majority of the baseline data for the analysis through the IMS-GIS Data Centre's data catalogue and database. Thanks to the GIS specialist and GIS data manager based on St Helena, the suitability assessment was run locally, without having to pay for an overseas consultant. This case study highlighted another main achievement of the IMS-GIS Data Centre in the context of a spatial planning and decision-making process. Not only data have been retained and managed locally, but also the technical expertise and knowledge on how to use the data and turn them into information came directly from the island. In this way, the IMS-GIS Data Centre proved that it has a positive long-term impact on the territories by favouring and enabling local people to learn about a multidisciplinary tool, build technical capacity and seize work opportunities, which in the past would have been given to overseas professionals.

4. MAIN RESULTS AND CHALLENGES TO BE ADDRESSED

The data management system introduced by the IMS-GIS Data Centre has showed that island-based data centres are a suitable and efficient support tool to spatial planning and decision-making processes. The examples of spatial planning support by the Centre have demonstrated that the direct participation and involvement of the stakeholders and spatial planners and the establishment of a "one to one" communication line between data users and data centre are fundamental for the success of the data services. A full-time data manager, and where is possible a team of data managers, is an essential element of the IMS-GIS Data Centre. Once contact with the data users is created, maintaining the data management system and the data services continuously can only be achieved by the full dedication of the data manager. For instance, a time-consuming task is gaining the trust from the practitioners and data users. Generally, people show resistance in two main areas: willingness to share data and fear of losing ownership of the data. A considerable amount of time in the initial phase of the development of the Data Centre was spent in providing data users and data collectors with evidence on how it would be advantageous and improve their way of working with and managing spatial data. Pilot projects worked out examples and one-to-one meetings with the stakeholders turned out to be useful solutions to demonstrate how the Data Centre operates for safeguarding ownership and intellectual property rights, for securing data with off-site back-ups and for enabling the access to data only through the data owners' authorisation. However, gaining stakeholders trust is a constant task because of the high turn-over of specialised workers on the islands and visitor researchers, which is typical of the SAUKOT. Therefore, there is a continuous need to introduce and train the new stakeholders to the local data management system.

Peoples' needs and aspirations in terms of use of data have been central to the development of the services. Designing the IMS-GIS Data Centre on open source software and the principle of simplicity was powerful. The data management system and its architecture have already been transferred to other territories outside the South Atlantic region, which present similar technical and socio-economic constraints. In 2018, thanks to a "Territory to Territory" project delivered in partnership with the JNCC, the system for harvesting and publishing metadata has been exported to Montserrat, where the Ministry of Agriculture, Trade, Housing, Land and Environment (MATHLE) requested a tool to discover its data, their availability, and accessibility. On top of these requirements, the tool needed to be managed locally, developed and implemented quickly, and had to ensure its long-term sustainability. Hence, the online metadata catalogue developed by the IMS-GIS Data Centre turned out to be a good solution. Training on how to set up and maintain the metadata catalogue were delivered in the Falkland Islands, where representatives of MATHLE were hosted for a week and in Montserrat, where the launch of the metadata catalogue online occurred shortly after (http://landinfo.gov.ms/Metadata.aspx). In 2019, the IMS-GIS data centre, thanks to the work in collaboration with the University of Dundee (Satellite Receiving Station) was commissioned by the JNCC to upgrade the metadata catalogue online to a full data portal (https://gisdataportal.gov.ms/).

The metadata catalogue has had a strong impact not only on data discovery but also on highlighting where data gaps exist. Therefore, the service can be used by the local governments to target their budgets and/or their support to projects that allow filling critical knowledge and data deficient areas. Not only the metadata catalogue allows a more thoughtful financial investment strategy, but it also enables researchers to write proposals for projects with a more practical and immediate application, above all in the spatial planning process. For example, overseas researchers were assisted in discovering information on target wildlife and locations which was used in support of the development of their research activity and related results (*e.g.*, Campioni *et al.*, 2017, Granadeiro *et al.*, 2018). At the same time, by speeding up the access to historic data, which used to be difficult to source, the metadata tool promoted the development of research projects focused on understanding the long-term effect of human-related activities on wildlife populations (*e.g.*, Clark *et al.*, 2019). It also helped fostering new networks of research collaborations amongst local partners and overseas researchers.

The IMS-GIS Data Centre, since it acts as a hub for the local data and promotes the concepts of data sharing and openness, has proven to facilitate the access to and visualisation of the data. As highlighted by the case studies, the data are now made open and available therefore, the sprout and growth of new spatial planning processes are facilitated. For instance, the data collected and derived through the Darwin Plus project in Saint Helena (Pike *et al.*, 2018) found immediate use in the assessment of suitable sites for a new landfill. Similarly, the data created during the Falkland Islands Marine Spatial Planning project were used as a baseline to develop a series of case studies on fisheries closure areas and now for a new Darwin Plus funded project to implement Marine Management Areas.

Although the IMS-GIS Data Centre has achieved considerable results, it continues to face challenges that have not yet been resolved. The information and technology facilities available on the islands determine how far the services can be provided locally. As it emerged from the case studies, the majority of the publicly-funded projects have been published online through the Lizmap web mapping application (Lizmap, 2018). However, due to the high cost of data usage via the Falkland Islands' local internet network and the satellite connection, and limited capital investment, all the webGIS projects have been published from servers remote to the islands. If this solution offers a good service for overseas researchers and potential data users, it is less convenient for those based on the islands as the internet costs are large. If data could be hosted locally, then a local network could be created free of charge in agreement whit the local internet provider. Only future changes in the local network design and improvements in the international internet connection will allow the development of local webGIS services, which would offer a cheaper and faster service for the islanders.

Long-term resourcing is a key challenge for the data centres on small islands. There are short-to-medium term grant schemes available to the small territories but it is rare to find funding resources or sponsors that will fund costs of a data management system specifically. Currently, in the Falkland Islands the approach adopted by the IMS-GIS Data Centre is to dedicate part of the budget of each SAERI-led research project benefiting data services to contribute to the running costs of the Data Centre and apply other fees for commercial works commissioned by the private sector. In other islands, such as Saint Helena, resourcing for the data centre is done by the way the local Government charges their internal departments for services. A solution to this challenge would be to see local governments, research institutions, and UK Government bodies to work more in synergy and to share a common data management funding strategy for the SAUKOT. Another solution would be to commercialise the provision of data services, above all when these are delivered to the private sector. However, this has so far only been pursued in the Falkland Islands (which has benefited from the presence of the hydrocarbons and commercial fishing industries) due to a lack of large private investors elsewhere. In conclusion, it emerges that identifying a budget that can pay for the long-term support of the IMS-GIS Data Centre has not been resolved yet and more work needs to be conducted for resourcing for its long-term sustainability.

Hiring a person for a full-time role of data manager is also challenging due to the combination of limited availability of financial resources and the physical remoteness of territories, such as the SAUKOT. Apart from the Falkland Islands, all the other territories have data managers that also cover other roles. As a result, the services are provided less continuously and are prioritised according to the rest of the tasks that the data manager has to accomplish. Appropriate resourcing is vital for the survival of any Data Centre. We recommend that for any Data Centre in small islands or territories, this should include adequate long-term provisions for not only the financial aspects of running a Centre but also other resources needed. Future-proofing a Centre in terms of technical requirements as well as staffing requirements is key to the long-term survival of any Data Centre.

As described in the case studies, webGIS applications have proven to be one of the best solutions for interacting with and informing stakeholders and the wider public since people can access data and information without having particular skills and abilities in using spatial tools, such as GIS. However, spatial planners have started requesting **"***living maps***"** since real-time data have become more common and are frequently available. Contrary to webGIS, that offers snapshots of reality, living maps are fed by a continuous stream of data coming either from remote devices or from computational systems that are set up to process data as soon as new ones are input. Similarly, the increase in the collection of data from remotely sensed devices, drones and "go-pro" above all, and the endless recording of photos and videos in many fieldworks, has prompted the need for a data management system specific to media files. Currently, living maps and dealing with media files are ambitious projects and challenges for a second phase of the IMS-GIS Data Centre.

5. CONCLUSIONS

The case studies brought as examples in this paper have demonstrated how the SAUKOT's IMS-GIS Data Centre has helped to support marine and terrestrial spatial planning processes, along with a range of research projects that fed data into planning activities.

Thanks to its integration with the local community, the Data Centre has provided the governments with the option to become less dependent on costly overseas consultants and to rely more on the data services offered "in house", with the result of investing in the development of government personnel's skills.

Similarly, because the Data Centre has been designed and built to be operational in remote islands of the South Atlantic Ocean, facing technological and financial limitations, then the simple data management concepts used to sustain the data management system have found their applicability to other realities sharing similar geographical and resource constraints. The case of Montserrat is an example of how another island has adopted and implemented the IMS-GIS Data Centre tools according to its necessities and capabilities.

Overall this paper has highlighted that spatial data management is crucial for both marine and terrestrial spatial planning processes especially for small territories or islands that must manage carefully the environment they rely on in the face of significant future changes ahead. Hence, the role and the utilisation of a data centre, once established, cannot be marginal or one-off, rather it should be integrated and become part of the baseline services that governments provide to their communities. It is recognised that resourcing for the long-term sustainability of the data centre is the main challenge that remote islands will face. Therefore, ahead of creating a data centre it is important to have a strategy that helps identifying and planning the sources of funding. The solution suggested here is an approach based on targeting multiple sponsors. Considering the size of the islands it is unlikely that the small governments can take the entire accountability of a data centre, hence partnerships with local or external research institutes, universities, NGOs and private/public bodies should be built. The investment from the engaged partners will be returned for example, in data services provided by the data centre.

The role and activities of the SAUKOT's IMS-GIS Data Centre presented here should therefore prove to be a useful example from which take further ideas and inspiration.

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