Sustainable Development Reform Hub
Law Building
The University of New South Wales
Sydney, NSW 2052, Australia

March 30th, 2022

Spatial Data Structures for Ocean Accounts

A Global Ocean Accounts Secretariat (GOAP) Technical report

Authors: Sophia German, GOAP Secretariat, Jordan Gacutan, Technical Officer, GOAP Secretariat

Acknowledgements
This report was made possible with support from the UK Government Blue Planet Fund

Recommended citation

This publication (and any material sourced from it) should be attributed as:
GOAP (2022) Spatial data structures for Ocean Accounts. Global Ocean Accounts Partnership, Sydney, Australia. https://www.oceanaccounts.org/spatial-data-structures-for-ocean-accounts/

Email contact: info@oceanaccounts.org

Website: www.oceanaccounts.org

Highlights

Ocean accounts:

- Organise ocean data (social, environmental, economic) into a common framework using the same structure as national accounts maintained by National Statistical Offices or Finance Ministries.
- Provide countries with the means to go beyond Gross Domestic Product (GDP) alone to measure progress towards growth and sustainability of the ocean economy.
- Provide a common information infrastructure for ocean policy, strategic planning (including marine spatial planning) and reporting.

Ocean Accounts are spatial:

- Ecosystem accounting requires an understanding of the extent of ecosystems and their condition within an accounting area.
- Ecosystems provide goods and services that contribute to economic activities, human health, and wellbeing.
- The supply of several ecosystem services is dependent on location: both ecosystems and the users of the service (e.g., coastal protection, recreation).
- Linking environmental to economic and social data could be achieved spatially.

Structuring spatial data through Ocean Accounts:

- Basic spatial units will be used to harmonise various levels of information (spatial and non-spatial) onto a standardised and uniform grid.
- Spatial data types, metadata standards, map projections and file formats discussed briefly.

Keywords: spatial data, data structures, System of Environmental-Economic Accounting

Table of Contents

Ocean Accounts for Sustainable Development

What are ocean accounts?

National accounts influence public policy — All countries maintain systems of national accounts, which inform and justify economic decision-making. The accounts are generally maintained by National Statistical Offices or Finance Ministries, based on the international standard System of National Accounts 2008 (SNA). They regularly produce and report the headline indicator of Gross Domestic Product (GDP).

Ocean accounts organise ocean data in a common framework, integrated with existing national accounts — Ocean accounts (OA) are integrated records of sectoral economic activity (e.g. sale of fish) or social conditions (e.g. coastal employment, inclusivity and poverty), and spatial environmental conditions (e.g. extent / condition of mangroves) that are compiled on a regular basis and are compatible with existing statistical standards. They are based on the SNA, and System for Environmental Economic Accounting (SEEA), which is now used by at least 80 countries to account for policy-relevant environment-economy relationships on land. At least 15 countries are actively developing ocean accounts.

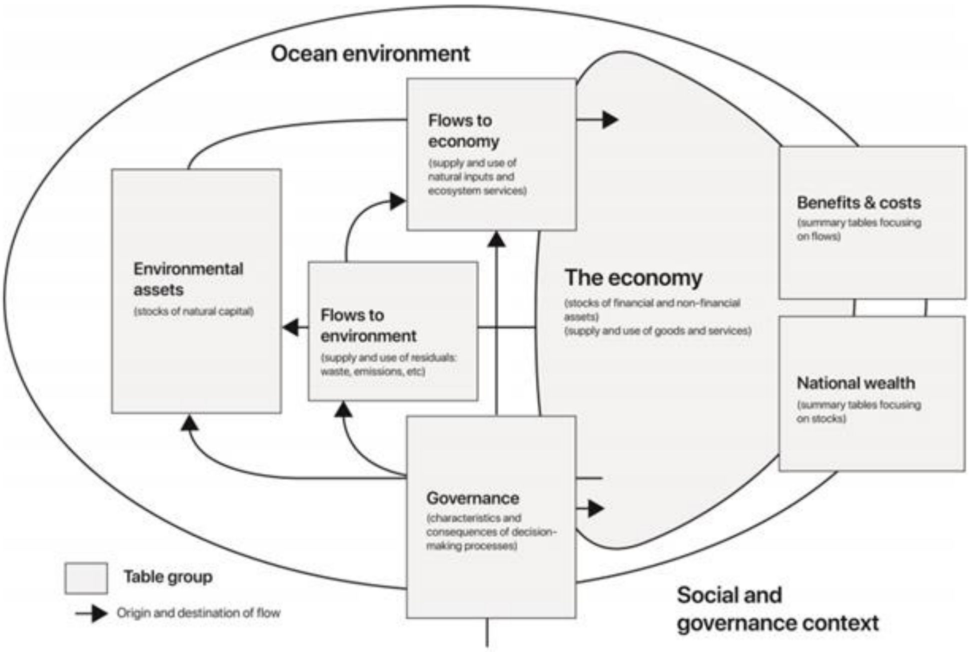

Figure 1. General structure of the Ocean Accounts Framework adapted from the Technical Guidance on Ocean Accounting (GOAP, 2021).

Why are ocean accounts useful?

Reporting of progress of the ocean economy towards growth, well-being and sustainability — A comprehensive sequence of ocean accounts enables countries to monitor three critical trends: (1) changes in ocean wealth, including produced assets (e.g., ports) and non-produced assets—e.g., mangroves, coral reefs; (2) ocean-related income and welfare for diverse groups of people—e.g. income from fisheries for local communities; (3) ocean-based economic production—e.g. GDP from ocean-related sectors.

Providing a common information infrastructure for ocean policy and reporting — Many ocean policy shortcomings arise from isolated information. Ocean accounts provide a common reference point for diverse policy questions, related to: (1) Ocean development—e.g., GDP in the shipping sector and associated GHG emissions; value-added in fisheries exports versus stock health and employment; (2) Marine spatial planning and area-based protection—e.g., changes in biodiversity or flows of ecosystem services like carbon storage or flood risk regulation; (3) International reporting—e.g., SDGs, Paris Agreement, CBD, etc.

Ocean Accounts are spatial

Ocean accounts require us to have a holistic understanding of how economic, social, and environmental factors are connected spatially. Location will dictate many aspects related to ocean accounts, including conservation status, governance, cultural value, biodiversity, and climate. Thinking spatially with Ocean Accounts requires that we use a spatial lens to store, manage, and interpret data. In doing so, it allows for more relevant and direct management strategies, and therefore better ocean accounting.

The extent of ecosystems and their condition within an accounting area is explicitly spatial. These characteristics need to be understood with reference to its location, since this may change who is responsible for the area, and can give an indication of the drivers, impacts, and pressures of that location.

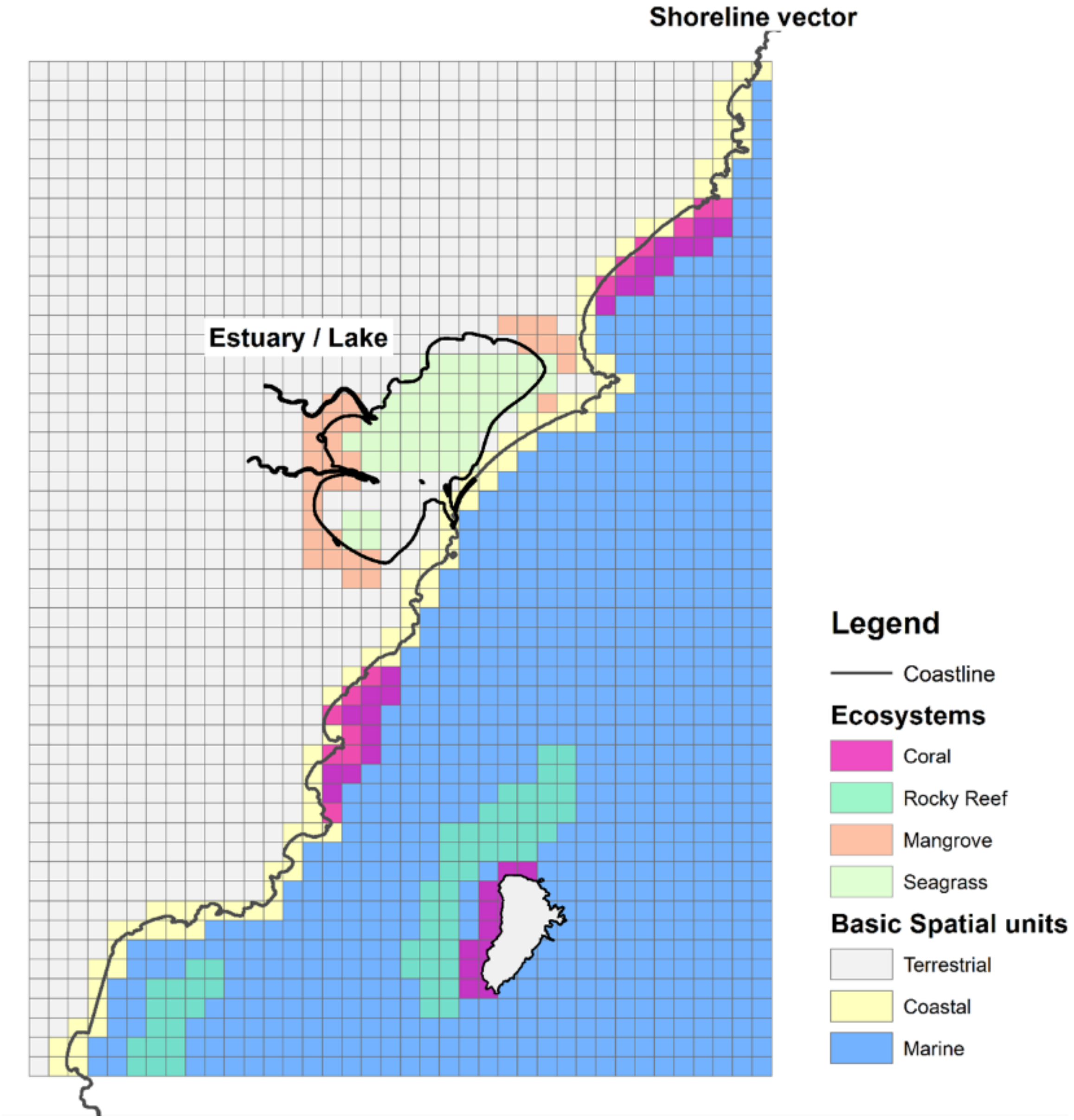

Figure 2. A theoretical example of an accounting area by Basic Spatial Unit (BSU), used for statistical reporting within Ocean Accounting. Each BSU contains multiple layers of data and knowledge on human activities, ecosystems / asset type (and their condition), layers of governance and other relevant information.

Thinking spatially with Ocean Accounts

Ocean accounts are aligned with the following standards: the UN System of National Accounts (SNA, 2008) in the treatment and measurement of economic sectors, activity and production, the UN System of Environmental-Economic Accounting – Central Framework (SEEA-CF, 2012) in the consideration of thematic flows from the environment to the economy (e.g., water, energy) and conversely, flows to the environment (e.g., waste, air emissions), and the UN Ecosystem Accounting (SEEA-EA, 2021) in the consideration and treatment of ecosystems, their extent, condition and services. The latter extends accounting to the spatial domain, in considering the extent and condition of ecosystems for a given accounting area. To uphold these standards, Ocean Accounts require good spatial data infrastructure.

Good spatial data infrastructure means that all datasets are accounted for and organised with common standards. This is a challenge for Ocean Accounts for several reasons. The ocean is vast and most of it sits beyond national jurisdictions, where datasets are collected at different scales – from local in-situ projects to satellites recording global ocean patterns. How ecosystems are defined will also differ, not to mention the extent of land cover types, where coastal areas might be measured in diverse ways. Groups and organisations use their own data collection and storage standards, and not all data is open source or updated on a regular basis.

We are dealing with a smorgasbord of datasets captured at different scales, with incompatible resolutions, in different data formats, with varying definitions of coastal regions, and so on. Data will span terrestrial and marine environments, and there needs to a be a systematic manner to organise such data.

The SEEA-EEA uses Basic Spatial Units (BSUs) to have a common reference for ecosystem types and assets. Spatial data are aggregated to BSUs, which are the smallest measurement units used for management and reporting purposes. Ocean Accounts will use this framework to organise and store spatial and non-spatial data compiled from several sources.

Basic Spatial Unit

The SEEA-EA provides guidance for the use of Basic Spatial Units (BSU), which subdivide an accounting area. BSUs will be used to harmonise multiple spatial and non-spatial datasets through converting information into a tabular format.

The goal of the BSU is to assign data (or parts thereof) to a single cell, to allow the comparison of multiple layers of data. Data within multiple BSU could then be assigned and aggregated to produce accounts for administrative or statistical reporting areas.

Guidance for the management of spatial Ocean data

In this section, we explain how spatial Ocean data can be linked with Ocean Accounts. First, current standards and new developments on spatial data infrastructure are discussed. Then, guidance is provided on how to standardise data through assigning each dataset to a spatial grid, and then how to convert those data into numerical values for interpretation. Each cell within the grid is called a Basic Spatial Unit, which will contain several elements of information stored in tabular format.

Taking stock of existing processes

The United Nations Initiative on Global Geospatial Information Management (UN-GGIM) is a knowledge base for geospatial data management. The UN-GGIM is accountable for the Global Statistical Geospatial Framework (GSGF), which facilitates National Spatial Data Infrastructure (NSDI). The goal of NDSI is to have standards for geospatial and statistical data that improve use and efficiency. This includes standardizing how data is collected, stored, and monitored.

The process of developing a spatial data infrastructure to support marine planning specifically has its benefits and challenges. In Greece, for example, marine spatial planning has become increasingly important, and yet the quality of available data is not meeting these needs (Vaitis et al., 2022). Therefore, having standards for content collection and harmonization methods is required to incorporate spatial datasets, but also those that are non-spatial, such as documents, articles, or spreadsheets. Their strategy adopted European metadata standards, and therefore all pieces of data had to be accounted for by a public sector organisation. Their software allowed for the simple visualisation of data on a map using their web-based platform.

In developing a framework for marine spatial data infrastructure, further interrogation into how datasets from marine, coastal, terrestrial, and freshwater are managed is necessary. While the GSGF has recommendations for how such datasets should be collated together in a geographical sense, further emphasis on the ocean is needed.

Planning for spatial data storage

Spatial data types

Geographic phenomena can be represented through discrete objects (e.g., buildings, governance, vegetation types) or continuous fields (e.g., elevation, precipitation, land surface temperature). There are two main data structures for geographic data, including vector (feature) or raster.

Vector data is comprised of vertices that can be stored as points, lines, polylines and/or polygons. Vector data is good for representing discrete objects that have precise boundaries, such as the outline of a building, or land zoning.

Raster data is a grid of tessellated tiles, where each tile (or cell) has a value. Raster data is good for representing continuous fields, especially for fuzzy boundaries, such as tidal regions, or mountainous landscapes. Raster cells suggest no internal variation within the cell.

Other data types can be joined with spatial data when there is a common field. Census data, for example, is tabular and stored within areal units known as SA1s. Since there is a polygon dataset of SA1s, the tabular data can be joined with it to visualise the demographics within that areal unit.

File formats of spatial data

There are several file formats that can store spatial data. Commonly used formats for vector data include shapefiles and google KML files. Commonly used formats for raster data include geoTIFF, JPEG and ASCII grid files. Geodatabases are directories that can store both vector and raster data. Geodatabases are an effective way to store spatial data since they use less space and data can be organised systematically. Users can create sub-folders known as feature datasets, which store feature data (like a shapefile). Furthermore, the user can decide on a common map projection to be used within the geodatabase.

Projections

Map projections are important to understand when using spatial data as they describe where the data is, and how it has been projected. Geographic coordinate systems use latitude and longitude to tell us where data is located on the world, whereas projected coordinate systems use linear units like metres to describe how the data is projected onto a 2D cartographic plane.

Common geographic coordinate systems in Australia include the Geocentric Datum of Australia (GDA, 1994 and 2020) and the World Geodetic System (WGS, 1984). The projected coordinate system for GDA is the Map Grid of Australia (MGA, 1994 and 2020) which has multiple zones.

Spatial data must be within a projected coordinate system to know where it is, and how to observe it. All datasets should be projected in the same way to make sure the data is aligned before any visualisation or analysis can commence. This can be checked within the properties or metadata. If the datasets are not within the same projection, then there may be errors in accuracy and precision. In this case, the data may require reprojecting, which is a common procedure in spatial analysis.

Metadata

Metadata describes the information related to the data and is good practice for responsible data management. Metadata should include the source, creation date, quality, condition, and other relevant characteristics. In Australia, we use the metadata standards from The Australian and New Zealand Land Information Council[1]. Metadata are important for spatial data as it allows for users to assess the usefulness of the data, interpret, and analyse it, and contact the data creator if necessary.

Standardising data to a Basic Spatial Unit (BSU)

BSUs will be used to store information extracted from spatial (vector and raster) and non-spatial (tabular) data in a gridded format to be standardised across Australia. Where data relating to ocean accounts is available and open source, it will be included. Metadata, file formats and map projections will be standardised to ensure identification of source, date, quality, and condition.

The process to convert spatial and non-spatial data into BSUs is delineated below. Each BSU will have its own accounting table, stored in text or SQL-based formats. Discussion of limitations are included. Practitioners may wish to disaggregate employment and production to higher-resolution statistical or reporting areas, which may span multiple cells of the spatial grid.

Vector

Vector data types include points, polygons, polylines, and lines. For ocean accounts, we will mostly be working with point and polygon types. Hereafter, we give examples of point and polygon data, how it will be represented within a BSU, and how it will be processed.

Point data include animal or plant sightings, points of interest, public transport stations, or anything else that can be represented by a single point location. Representing point data within a BSU will occur through counts and/or values that occur within the gridded cell. It is important to remember that environmental point data such as plant or animal sightings are not entirely representative of their actual distribution but can offer valuable information about the potential habitats and their ecosystems. Points can be joined spatially with the grid to give a count of the data within the BSU, I.e., it will be aggregated to the same level as the BSU.

Polygon data include administrative areas, vegetation types, land zoning, or anything that can be represented through drawing a shape around it. Representing polygon data within the BSU will occur using a Boolean framework, i.e., presence or absence. Polygon data that is bigger than the BSU will be disaggregated to the size of the grid, and then the area that

---

[1] See here for metadata guidelines: https://www.anzlic.gov.au/resources/asnzs-iso-1911512015-metadata

each polygon takes up of the BSU will be calculated. If the BSU sits within two polygons that contain categorical information, e.g., local government areas, the one that takes up most of the space will be the one listed in the table. The same process would occur if there were multiple polygons with quantitative values within the same BSU. This process is a coarse approximation to identify the BSUs are pertaining to one category above another and can therefore be biased in what is being represented (see section 3.3.4).

Raster

Raster data is used for continuous phenomena such as climate or elevation. While already in gridded format, raster data may need to be further processed to match the resolution of the BSUs. Raster data will need aggregating in the case where raster resolution is higher than the BSU. In this case, raster values can be averaged, which means that some details are lost. Where raster resolution is lower, raster values will require disaggregating. In this case, the same raster value will be assigned to multiple neighbouring cells, to match the resolution to that of the BSU.

Non-spatial data

Ocean accounts contain governance accounts, which are based on non-spatial data (e.g., policies, legislation, traditional knowledge, and other layers governance). Whilst challenging, converting such knowledge and data into the spatial domain can be achieved if administrative areas are known. For example, environmental legislation and policies may refer to limits / jurisdictions such as above or below the high-water mark, sub-tidal or intertidal areas. They may also refer to specific government/administrative areas, which are usually defined spatially. Thus, non-spatial could be related to the BSUs coinciding with such descriptions. Summarise data as numerical values (where feasible, laws and policy remain as free text).

Limitations

In aggregating or disaggregating data to fit within BSUs, a statistical bias known as the Modifiable Areal Unit Problem (MAUP) can occur. The MAUP happens when the size of area – or how something has been subdivided – influences both the values within it and subsequently, it’s statistics. When values within BSUs are smoothed out, this becomes a potential issue in analysis and interpretation.

Worked example of dealing with spatial data

Working with spatial data can differ from place to place. Data availability and quality, for example, is often related to geopolitical context. Frequency of data collection and monitoring of ecosystems is also related to location, where oftentimes data is stored in paper maps that may have outdated information. Digitising is a common process to store such data digitally. Below we provide an example of dealing with spatial data for ocean accounting. GOAP recently led a pilot study in Fiji with a focus on mangroves, and here we describe how data were prepared for analysis.

Background

Ocean economy is fundamental to Fiji's national economy, and for supporting the livelihoods of the Fijian people. However, until recently, its value to the real economy and the society remains less readily realised.

Mangroves are a wide-spread coastal habitat in Fiji of national significance. Present in all provinces, they are abundant in river deltas and estuaries. Mangroves have previously been demonstrated to enhance commercial and subsistence fisheries, protect coastlines from wind and wave energy, sequester carbon and are of cultural significance to Fijian coastal communities.

Knowledge of mangroves and their contribution to society and the economy is fragmented. While the extent of mangroves has been mapped, moving forward, the estimates could be refined. The condition of mangroves (in terms of health and selected functions) haven been estimated. The estimation and valuation of services and benefits are performed using a variety of methods, many of which are incompatible with accounts maintained by the Ministry of Economy. To adequately manage these habitats, managers must understand their distribution and measure their importance to society and the economy, to provide more equitable and sustainable decisions.

Compiling and maintaining mangroves accounts requires data on the spatial extent of mangroves, the primary production and associated carbon storage, and the secondary production (i.e., of reliant species) generated in these forests.

Measuring mangrove extent and condition

Data on the extent and condition of mangroves is available for Fiji, with coverage and quality developing rapidly within the last decade. In 2018, the Global Mangrove Watch Initiative released a new global baseline which estimates the total mangrove forest area of the world as of 2010 at 137,600 km2 (53,100 sq mi), spanning 118 countries and territories. Other global initiatives map mangrove extent as part of natural forest assessments and change in global forest cover. Few datasets, however, possess the temporal resolution needed to maintain extent and condition accounts, and few examples exist of further relating these accounts to flows to the economy and society.

Fijian mangroves belong predominantly to the genera *Rhizophora spp.* (*R. selala, R. Stylosa*) and *Bruguiera spp.* (*B. gymnorrhiza*), across coastal, deltaic, and riverine environments. The extent of mangroves was determined using open-source data from the Global Mangrove Watch.

Spatial data was processed to be included within the grid. In its original format, Global Mangrove Watch data is in raster format. This was converted to a vector polygon format, and then projected into WGS84 to align with other datasets. The area for each mangrove patch was calculated and summed per BSU.

The density of mangroves was mapped for 10 provinces, with the grids were then aggregated per provincial administrative area, to calculate the area of mangrove per province.

On-ground data was not available for this exercise and therefore modelled estimates using existing values from the literature were used to estimate four condition variables across Fiji. The four condition variables included maximum tree canopy height, basal weighted tree height, above ground biomass and net primary production.

To align mangrove extent and condition, a grid was produced for the entire area of Fiji, including land, territorial waters, and exclusive economic zone. In considering computing power and the resolution of datasets, a 1 km2 grid size was chosen, which defines the BSU for analysis. As mangroves are predominantly in coastal areas, a subset of the grid (henceforth 'coastal grid') was made in selecting grids within 1 km of the Fijian shoreline. Each unit of the coastal grid was then assigned to an administrative area, as one of fourteen provinces within Fiji. Coastal grids were assigned through intersections (i.e., physically within the administrative area). For coastal grids that did not intersect with an administrative area, the closest area by distance to the shoreline was assigned.

Ecosystem services (flows to environment)

Mangroves are an important ocean asset for Fiji on which a significant share of local population in coastal and maritime zones depend on. Organising spatial data to represent the environmental and economic benefits of mangrove ecosystems is therefore a very important task.

Discussion and conclusions

There are several methods and standards for spatial data management, and yet these standards are lacking for ocean environments. Ocean environments include marine, coastal, aquatic, and terrestrial landscapes, and have an accounting system that is standard across all environments is necessary.

Here, we presented a process guidance on the management of spatial data for Ocean Accounts. The purpose of this document is to describe the development of a framework that accounts for spatial ocean data and ways to standardise this information. In collating spatial data, there are several steps to take to visualise them correctly in the geographical sense. Datasets need to be in the same map projections, contain correct metadata that are up to scratch, and be within the right format. This is usually the case when working with spatial datasets and is an important step. From there, spatial, and non-spatial data can be joined together and stored within the proposed gridded format, and then translated into SQL tables for subsequent analysis, interpretation, and management.

The handling of non-spatial data will be through SQL accounting tables. There are several benefits to using SQL, such as its well-documented language, consistency, and rational, tabular data. However, in some cases, data relevant to Ocean Accounts may suit a more flexible format, such as NoSQL databases. In that case, future avenues may consider NoSQL ontologies.

References

GOAP 2021. Ocean Accounting for Sustainable Development, Detailed Technical Guidance for account compilers, data providers, and end-users (v0.9, global consultation). *In:* BORDT MICHAEL, MILLIGAN, B. & PRAPHOTJANAPORN, T. (eds.) *Ocean Accounting for Sustainable Development.* Global Ocean Accounts Partnership.

VAITIS, M., KOPSACHILIS, V., TATARIS, G., MICHALAKIS, V.-I. & PAVLOGEORGATOS, G. 2022. The development of a spatial data infrastructure to support marine spatial planning in Greece. *Ocean & Coastal Management,* 218**,** 106025.