White Paper
on
Readily Available and Accessible (Open) Marine Geospatial Information

A reference on the benefits and challenges of managing and providing accessible marine geospatial information

Working Group on Marine Geospatial Information
United Nations Committee of Experts on Global Geospatial Information Management
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Table of Contents

Abbreviations

ARHC	Arctic Regional Hydrographic Commission
ARMSDIWG	Arctic Regional Marine Spatial Data Infrastructure Working Group
AVPG	Arctic Voyage Planning Guide
CDS	Concept Development Study
EEZ	Exclusive Economic Zone
FAO	Food and Agricultural Organization
FELA	Framework for Effective Land Administration
FIG	International Federation of Surveyors
GEBCO	General Bathymetric Chart of the Oceans
GIS	Geographic Information System
GML	Geography Markup Language
GNSS	Global Navigation Satellite Systems
GSGF	Global Statistical Geospatial Framework
HO	Hydrographic Office
IBCAO	International Bathymetric Chart of the Arctic Ocean
IGIF	Integrated Geospatial Information Framework
IHO	International Hydrographic Organization
IMO	International Maritime Organization
IOC	International Oceanographic Commission
ISO	International Organization for Standardization
LINZ	Land Information New Zealand
MGI	Marine Geospatial Information
MOU	Memorandum of Understanding
MSDI	Marine Spatial Data Infrastructure
MSP	Marine Spatial Planning
NSDI	National Spatial Data Infrastructure
NOAA	U.S. National Oceanic and Atmospheric Administration
NZMGI-WG	New Zealand Marine Geospatial Information Working Group
OGC	Open Geospatial Consortium
RHC	Regional Hydrographic Commission
SDG	Sustainable Development Goal
SDI	Spatial Data Infrastructure
SPSLCMP	South Pacific Sea Level and Climate Monitoring Project
SCUFN	Sub-Committee on Undersea Feature Names
UN	United Nations
UN-GGIM	United Nations Committee of Experts on Global Geospatial Information Management
UNCLOS	United Nations Convention of the Law of the Sea
UNESCO	United Nations Educational, Scientific and Cultural Organization
WG	Working Group
WG-MGI	Working Group on Marine Geospatial Information
WMS	Web Map Service
XML	Extensible Markup Language

Executive Summary

The United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) at its ninth session in August 2019 recognized that marine geospatial information must be made available and accessible for a multiplicity of purposes. The Committee of Experts invited the Working Group on Marine Geospatial Information (WG-MGI) to consider the variety of marine data sources that might be made available and to provide real-world examples of the benefits of and the need for readily available and accessible marine geospatial information. In this regard, the Committee asked the Working Group to consider coastal zones and inland waterways and water bodies, existing geospatial data management practices (including the Integrated Geospatial Information Framework and the Framework for Effective Land Administration), and the potential for capacity development to strengthen marine geospatial information capabilities in developing countries and small island developing states (UN-GGIM Ninth Session, [E/2020/46; Decision 9/108]).

Approximately 70% of the Earth's surface is water—lakes, rivers, tributaries, deltas, seas, and oceans. Water is critical to socio-economic development, energy and food production, healthy ecosystems, and to human survival overall. Water is at the heart of adaptation to climate change and serves as the crucial link between society, the global economy, and the environment. More than four billion people depend on marine waters for fish as a primary source of protein (Food and Agricultural Organization 2014), and the International Maritime Organization (IMO) estimates that 90% of the world's trade is conducted upon the seas and oceans (IMO 2015).

As global reliance on water and its resources increases, marine geospatial information is needed by governments to support data-driven, evidence-based management and administration of seas, oceans, coastal zones, and inland waters. Knowing *where* people, marine life, events, and activities are, and their spatial relationships to one another, is essential for informed policy and decision-making (e.g., Marine Knowledge 2020[1]). The timeliness of such data is of equal importance. Real-time geospatial information (e.g., met-ocean data) is needed to prepare for and respond to emergency situations, such as natural disasters, but real-time or near real-time data can also help governments develop strategic priorities and measure and monitor outcomes, including the 2030 Agenda for Sustainable Development.

The 2030 Agenda for Sustainable Development is a global plan for action and a commitment to eradicate poverty and achieve world-wide sustainable development by 2030. The Agenda includes 17 Sustainable Development Goals (SDGs) and 169 targets which measure progress towards global sustainability. Each of the 17 SDGs has a strong relationship with water and requires access to geospatial data that adhere to international standards to make evidence-based decisions and to monitor SDG progress. Furthermore,

[1] https://audiovisual.ec.europa.eu/en/video/I-066877?lg=OR

geospatial data from offshore and inland waters must be interoperable with one another and with terrestrial and atmospheric geospatial data to provide a comprehensive analysis of SDG progress.

Unfortunately, marine geospatial information may not be readily available and accessible for policy and decision-making. Consequently, increasing the availability and accessibility of comprehensive location-based information can benefit many sectors within the marine domain, including commercial shipping and safe navigation; management of marine resources, the Blue Economy, and marine spatial planning; emergency management and response; maritime limits and administration of spaces; and law enforcement and defence. Additionally, access to marine geospatial information can provide the data needed to monitor progress towards national and global strategic priorities.

Given the urgent, global need for access to marine geospatial information, the Working Group recognized that providing guidance on managing and providing access to marine geospatial information might encourage countries to make standardized and fit-for-purpose marine geospatial information available. While the benefits and challenges of providing easy access to marine geospatial information are conceptually well-understood, documenting these issues and their solutions in real-world experiences remains a critical need.

Thus, the Working Group undertook a use case exercise with a hypothetical scenario to understand how countries currently manage and provide marine geospatial information. This whitepaper reports on the conclusions from that use case exercise and related case studies volunteered by members of the Working Group, and seeks to:

- demonstrate the benefits of readily available and accessible marine geospatial information conceptually and with real-world examples;
- provide information on the challenges many countries face when it comes to providing access to marine geospatial information;
- discuss standards for data and the types of data to make available; and
- offer guidance on actions countries can take to enhance the availability and accessibility of marine geospatial information to realize its widest and fullest utility.

This paper and its recommendations take into account other United Nations frameworks for geospatial information management, including the overarching and strategic Integrated Geospatial Information Framework (IGIF), the Global Statistical Geospatial Framework (GSGF), the Framework for Effective Land Administration (FELA), and the Global Fundamental Geospatial Data Themes, discussed in more detail below.

Within this White Paper, "marine" refers to the traditional maritime domain—seas, oceans, and their ports and harbors, and to the remaining 70% of Earth's surface covered by water—coastal zones, deltas, inland waterways and water bodies, as provided under the Working Group's terms of reference endorsed by UN-

GGIM. “Geospatial data” and “geospatial information” are used interchangeably in the IGIF in the general contexts. In specific contexts, “geospatial data” refers to unprocessed facts and figures; “geospatial information” refers to data that has been processed, organized, structured, and presented in a meaningful way.

The purpose of this White Paper is to document the results of the use case exercise and is intended to serve as a reference for Member States to improve the availability and accessibility of marine geospatial information for the benefit of society, environment, and economy.

Global Drivers

The major global agendas and frameworks that have driven and guided the consideration and preparation of this paper and the use case exercise are discussed below.

The 2030 Agenda for Sustainable Development

The 2030 Agenda for Sustainable Development—adopted by world leaders in September 2015 at an historic United Nations Summit—officially came into force on 1 January 2016 with 17 Sustainable Development Goals (SDGs). From 2016 through 2030, the SDGs apply to all countries and will mobilize efforts to end all forms of poverty, fight inequalities, and tackle climate change, while ensuring that no one is left behind. The 17 SDGs and 169 targets demonstrate the scale and ambition of the agenda.

Figure 1: Sustainable Development Goals (SDGs) [2]

The SDGs call for action by all countries to promote prosperity while protecting the planet. The SDGs recognize that ending poverty goes hand-in-hand with strategies for economic growth, with addressing societal needs including education, health, social protection, and job creation, and with tackling climate change issues, biodiversity loss, and environmental protection.

[2] https://sustainabledevelopment.un.org/?menu=1300

The United Nations Integrated Geospatial Information Framework

UN-GGIM, at its eighth session in August 2018, adopted the Integrated Geospatial Information Framework (IGIF). The IGIF provides a basis, a reference, and a mechanism to establish, strengthen, or improve national geospatial information management. The IGIF also helps coordinate activities to achieve alignment between existing national capacities, capabilities, and infrastructures, including those regarding the marine domain. The IGIF aims to translate high-level concepts to practical implementation guidance for use by Member States and does so by leveraging seven underpinning principles, eight goals, and nine strategic pathways (Figure 2).

The IGIF comprises three parts as separate, but connected, documents:

- Part 1 is an Overarching Strategic Framework;
- Part 2 is an Implementation Guide; and
- Part 3 is a Country-level Action Plan.

The three parts of IGIF serve a country's need to address social, environmental, and economic issues which depend on continually changing, location-based information. The IGIF focuses on location-based information that can be integrated with other meaningful data to solve societal and environmental problems, to stimulate economic growth and opportunity, and to create or measure progress towards a country's development priorities and the Sustainable Development Goals.

Part 1: Overarching Strategic Framework

Part 1 provides the context of *why* geospatial information management needs to be strengthened and *why* it is a critical element of national social, economic, and environmental development. The Overarching Strategic Framework focuses on the role of geospatial information in the digital age and how geospatial information is integral to government decision-making at all levels.

Part 2: Implementation Guide

Part 2 describes *what* actions can be taken to strengthen geospatial information management. The Implementation Guide is a reference that provides information for governments to design, plan, establish, implement, and sustain nationally integrated geospatial information management in their country so that transformational change is enabled, visible, and sustainable.

Part 3: Country-level Action Plan

Part 3 is specific to each country and details *how* the guidance, options, and actions specified in the Implementation Guide will be carried out, when, and by whom. Importantly, the country-level Action Plan is a plan, not a program that is implemented.

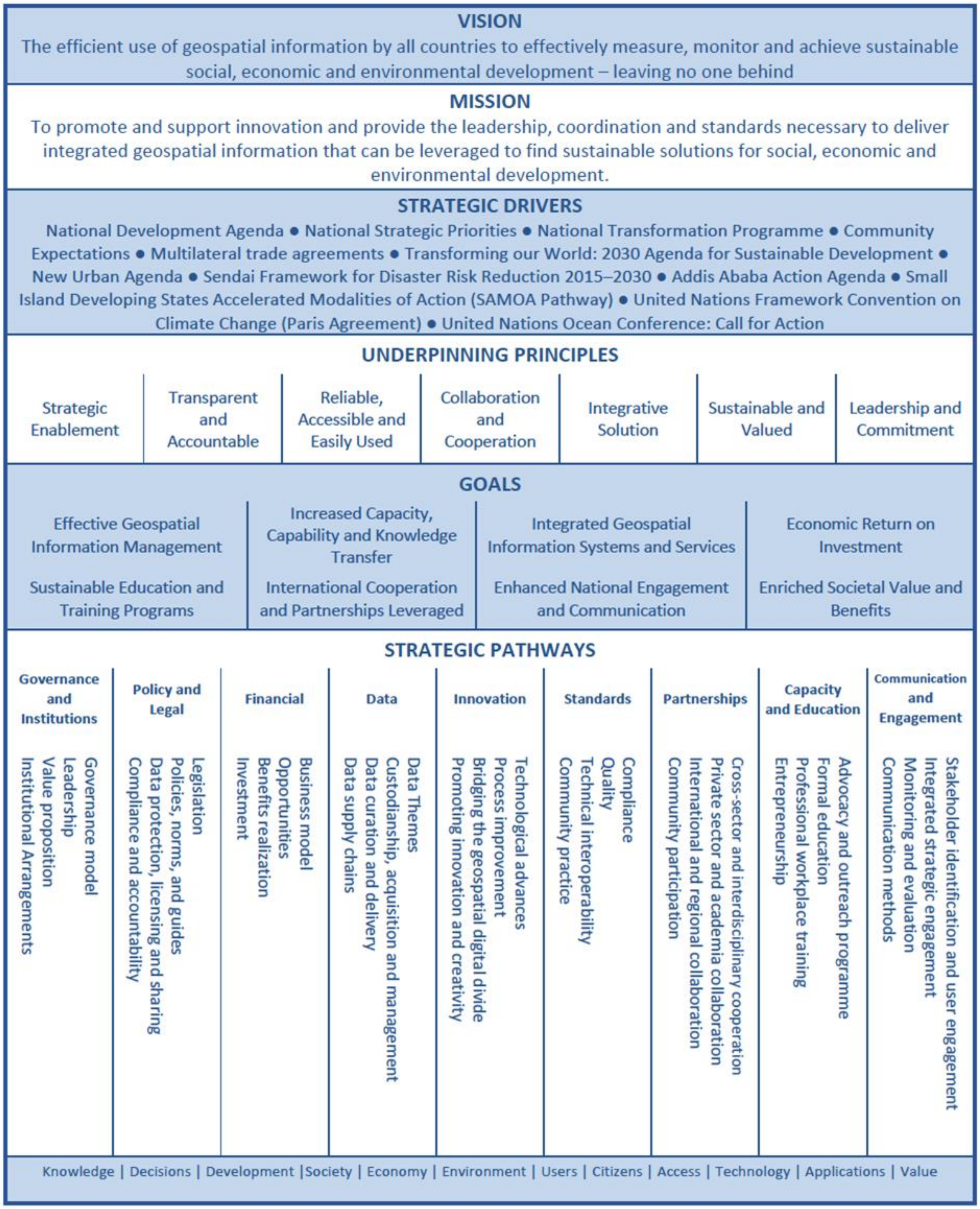

Figure 2: Integrated Geospatial Information Framework (IGIF).

The Working Group on Marine Geospatial Information is in the early stages of considering integrated marine geospatial management and hopes to provide further guidance on implementing the IGIF for the marine domain, similar to the guidance provided in the Framework for Effective Land Administration (FELA) for the land domain.

The United Nations Framework for Effective Land Administration

The Framework for Effective Land Administration (FELA) is a reference on developing, renewing, reforming, strengthening, and modernizing land administration and management. The FELA directly relates to the overarching Integrated Geospatial Information Framework (IGIF) adopted by the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM). FELA implements the IGIF for the land domain (Figure 3).

FELA Goals	FELA Requirements	FELA Pathways
Transparency and accountability increased	Accountable and transparent governance	Governance, Institutions and Accountability*
Gender-responsive and inclusive of vulnerable groups	Inclusive and recognizes all forms of tenure	Policy and Legal
Affordable investments and economic return assured	Affordable with sustainable business models	Financial
Reliable data and service quality attained	Data maintained, secure and not duplicated	Data
Responsible and innovation oriented	Upgradable systems and approaches	Innovation
Interoperability and integration supported	Considers internationally agreed standards	Standards
Cooperation, partnerships, and participation leveraged	Strengthens partnerships and supports collaboration	Partnerships
Capacity, capability, knowledge transfer and exchange attained	Facilitates capacity development and knowledge transfer and exchange	Capacity and Education
National engagement and communication enhanced	Advocates for effective land administration	Advocacy and Awareness*

Figure 3: Overview of FELA's requirements and goals.

The United Nations Global Statistical Geospatial Framework

The Global Statistical Geospatial Framework (GSGF) facilitates the integration of geospatial information, statistics, and other data to inform and facilitate data-driven decision-making in support of national and local development priorities.

The United Nations Strategic Framework on Geospatial Information and Services for Disasters

This Framework helps Member States and other concerned entities benefit from applying geospatial information and services across all phases of disaster risk management. The Framework emphasizes the fundamentals of sustainability, accessibility, and interoperability of geospatial information and services for disaster risk reduction and management.

The United Nations Global Fundamental Geospatial Data Themes

The Global Fundamental Geospatial Data Themes are collectively a set of 14 individual data themes which can be harmonized to enable the measurement, monitoring, and management of sustainable development in a consistent way over time and to facilitate evidence-based decision- and policy-making. Each theme is a high-level categorization of a subject on which data can be collected (Figure 4).

Figure 4: The Global Fundamental Geospatial Data Themes.

Marine geospatial information connects and contributes to each theme. Descriptions of the fundamental geospatial data themes and their relation to water and to marine geospatial information are further discussed in Table 1.

GLOBAL GEODETIC REFERENCE FRAME	*Allows users to precisely determine and express locations on the Earth, as well as to quantify changes of the Earth in space and time. It is not a data theme in the sense of the other themes, but a prerequisite for the accurate collection, integration, and use of all other geospatial data.*
ADDRESSES	*Addresses underpin government administration at all levels; and good administration is a prerequisite for achieving sustainable development goals. An address is often the unit to which a public service, such as water, is provided. Addresses also enable effective communication with citizens; informing them of policies applying to them, and notifying them of relevant incidents.*
BUILDINGS AND SETTLEMENTS	*Buildings and settlements are the structures and locations in which populations live and carry out economic activity. This theme's main use is to locate population and its distribution. This dataset is needed for a variety of use cases, such as resource management and disaster preparedness.*
ELEVATION AND DEPTH	*This theme describes the surface of the Earth both on land and under a body of water, relative to a vertical datum. Elevation is essential to delineate drainage basins in hydrology, to forecast physical phenomena (e.g., flooding), to understand climate change, etc. Depth plays a key role in the effective governance, management, and sustainable use of the oceans and marine resources*
FUNCTIONAL AREAS	*Are the geographical extent of administrative, legislative, regulatory, electoral, statistical, governance, service delivery, and activity management areas. Functional Areas can be used to visualize data, for analytical purposes and for trends over time. In the marine environmental context, they are key units for implementation and monitoring.*
GEOGRAPHICAL NAMES	*Provide orientation and identity to places, they are location identifiers for cultural and physical features of the real world. Geographical names are also required for a wide range of topographical and thematic map outputs at any scale. They are necessary for a consistent communication and visualization of any SDG-related issue or action.*
GEOLOGY AND SOILS	*Describe the Earth's surface for land and marine environments. Geology data can reveal risks to population in the form of earthquakes, volcanoes and landslides; and opportunities in the form of aquifers, mineral and fossil fuel resources. Soils include permafrost, wetlands, non-soil environments, and underwater sediments*
LAND COVER AND USE	*Land cover represents the physical and biological cover of the Earth's surface. Land use is the current and future planned management, and modification of the natural environment for different human purposes or economic activities. Land Cover includes artificial surfaces, agricultural areas, forest, semi-natural areas, wetlands and waterbodies etc.*
LAND PARCELS	*Areas of land or more generally of the Earth's surface (land and/or water) under common rights (such as ownership or easements), claims (such as minerals or indigenous land) or use.*
ORTHOIMAGERY	*Is geo-referenced rectified image data of the Earth's surface including coastal zones and banks of inland water bodies and waterways, from satellite or airborne sensors.*
PHYSICAL INFRASTRUCTURE	*This theme includes industrial and utility facilities and service delivery facilities, such as water supply, sewage, storm water drainage, dams, levees, and weirs, and telecommunications services.*
POPULATION DISTRIBUTION	*Geographical distribution of people, including population characteristics. This theme is vital to understand the spatial distribution of the population and its characteristics, as well as how population impacts urbanization, regional development, or sustainability - including how populations are distributed throughout coastal areas.*
TRANSPORT NETWORKS	*Are the suite of road, rail, air, cable, and water transport routes and their connectivity. Water within this theme includes water in all three states - fresh, brackish, and salt - and includes rivers, lakes, reservoirs, marine, and glacial features.*
WATER	*Extent and conditions of all water features including rivers, lakes and marine features. Water is critical to sustainable development. From a human-centered systems perspective, water is a precious natural resource, vital for life, development and the environment, depending on how it occurs and how it is managed.*

Table 1: The global fundamental geospatial data themes and their relationships with water and marine geospatial information.

Use Case Exercise

The working group undertook a use case exercise to better understand the issues, challenges, and benefits of managing and providing open (readily available and accessible) marine geospatial information, and to consider feasible solutions to address common issues and challenges.

The use case exercise outlined a hypothetical scenario followed by five questions which were aimed at understanding the practices and challenges a Member State faces when providing open marine geospatial information. Respondents were asked to assume that they are the persons responsible for the hydrographic surveying of Country A in the scenario and to assume that Country A's policy and legal framework is identical to that of their own Member State. The Working Group recognized that each respondent may not be aware of their State's policies on certain geospatial data management issues, and in those cases, the Working Group asked respondents to answer to the best of their knowledge. The Working Group also recognized that the fictitious scenario may not be applicable to each respondent's Member State. Thus, the Working Group asked that respondents consider the scenario as potential context for thought when answering the survey questions. The scenario and survey are included below.

Exercise Scenario

Country A is demolishing a large chemical storage facility on its coast. Country A needs to design protective measures if, during the demolition, toxic chemicals are leaked into Country A's coastal waters. The hydrographic office of Country A has been asked to provide geospatial data on those coastal and nearby inland waters, so that Country A can predict if the chemicals will reach and contaminate the inland water supply. There is also a possibility that chemicals released from the storage facility will reach inland waters of neighboring Country B. Currently, Country A has no agreement on sharing geospatial information with Country B.

Exercise Questions

1) How does your country organize and manage marine geospatial information (e.g., spatial data infrastructure)?
2) How are data added to or integrated with existing geospatial data, including land-based data?
3) How can or do you share and integrate your data with other national agencies?
4) Do you have any international, cross-agency, or non-governmental partnerships that facilitate the collection, sharing, and maintenance of data?
5) What legal and logistical barriers do you know of or foresee in using a multilateral approach to managing and sharing data (i.e., marine spatial data infrastructure)?

Readily Available and Accessible (Open) Marine Geospatial Information

The value of marine geospatial information is often defined in terms of safe navigation, which has been the foundation for discovery and economic development all over the world. While safe navigation is still a fundamental mission, growing utilization of the marine domain and its resources require marine geospatial data of a variety of sub-themes and data types—not solely navigational products. Now, more than ever, standardized, accessible, and fit-for-purpose marine geospatial data are essential to support national infrastructure and sustainable development of the marine domain. Numerous maritime activities, such as coastal zone management, hazard response and mitigation, national defence, and maritime boundary delimitation, require access to marine geospatial information (International Hydrographic Organization 2018). Based on responses to the use case, outcomes from the Working Group's meetings, and current literature, the Working Group has focused on some of the benefits to be gained by all stakeholders from easy access to marine geospatial information, as well as some of the challenges stakeholders face when managing, providing, and utilizing marine geospatial information.

Benefits

The Working Group has separated the discussion on benefits into five main categories—commercial shipping and safe navigation; management of marine resources, the Blue Economy, and marine spatial planning; emergency management and response; maritime limits and administration of spaces; and law enforcement and defence (Brinkman and Caverley 1992; International Federation of Surveyors [FIG] 2008). Each category demonstrates the close and integrated relationship that marine geospatial data have with a country's, agency's, or person's ability to thrive in the marine domain. This is not an exhaustive discussion of the benefits marine geospatial information can provide, but the discussion serves as a reference on the myriad ways that access to marine geospatial data can benefit countries, agencies, and other stakeholders.

Commercial Shipping and Safe Navigation

Marine geospatial information can provide many economic benefits to the commercial shipping industry. Commercial shipping requires up-to-date nautical chart data to create the most efficient shipping routes and to maximize the amount of cargo transported. Accurate charting provides the most direct routes between ports, reduces the labor required to operate vessels, decreases the number of groundings, and allows the transit of deeper draft vessels in shallow waters. One study in Tampa, Florida found that an additional foot of draft can create between $36,000 and $288,000 USD of increased profit per transit (NOAA 2000). These economic gains can surpass that of other means of transport (e.g., rail and air) when there are not strict time constraints (FIG 2010).

Commercial shipping also offers one of the lowest carbon footprints compared to other means of transport (Figure 5; FIG 2010), and the industry has efforts underway to further reduce their emissions and carbon footprint. Efforts are currently focused on improvements to fuel economy and the introduction of new, larger, and more efficient vessels, slow steaming, and technical modifications to existing ships. Most new ships built by World Shipping Council Member companies since 2013 are approximately 30 to 40% more carbon efficient than those ships they replaced (World Shipping Council 2020). Access to marine geospatial information can help the industry realize these environmental benefits by shortening transportation time and costs and making commercial shipping a more viable transport option.

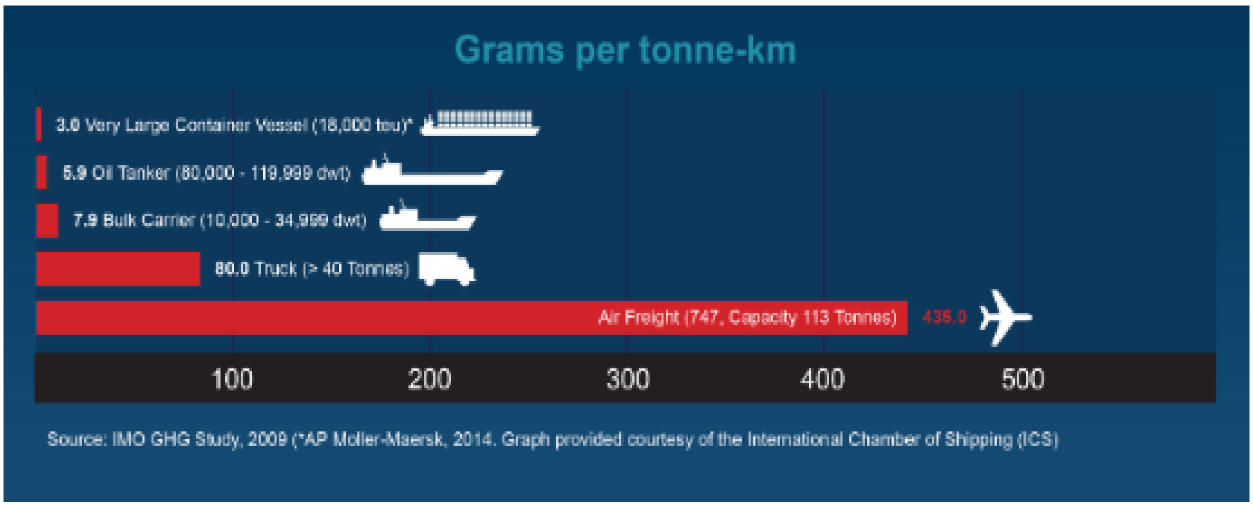

Figure 5: The carbon footprint of different transportation options (World Shipping Council 2020).

Access to marine geospatial information can also mitigate safety risks related to commercial shipping. Marine accidents killed 1,163 people and caused $197 million in insured losses in 2017 (Insurance Information Institute 2018). Commercial shipping is a growing industry and seaborne trade is expected to double that of the previous decade by 2031 (UNCTAD 2008). The industry requires access to high quality, fit-for-purpose marine geospatial data to avoid a concurrent increase in the number of maritime accidents.

For example, experts anticipate commercial shipping to grow rapidly in the Gulf of Guinea in Africa, but many of the charts for that area are more than 25 years old and were created without global navigation satellite systems (GNSS) or modern echosounders. Recent hydrographic surveys found discrepancies between 35 and 125 meters in shoreline features and between 0.5 to 5.8 meters in depths. The lack of current marine geospatial data could present a serious problem as commercial shipping in the area expands. Vessels may ground or may not operate at full capacity due to fear of grounding, and the area is likely to lose some of the economic and environmental benefits associated with the expansion of the industry. Additionally, in some areas with inadequate charting, companies may minimize their investment and deploy an older fleet that is more likely to become involved in a marine accident (Brinkman and Caverley 1992).

While all stakeholders can benefit from access to marine geospatial data, those benefits are especially important to the Gulf of Guinea and similar places around the world where data are outdated or to countries that do not have the means to collect such data. Access to marine geospatial information can help those countries sustainably manage their marine domain and remove the barrier to entry into the larger geospatial community. Ultimately, increasing access to marine geospatial data can help countries maximize the economic and environmental benefits of marine transportation while reducing the risk for a growing industry.

Management of Marine Resources, the Blue Economy, and Marine Spatial Planning

Regulation of marine resources, living and mineral, is vital to sustainable use of marine spaces. There are a wide range of activities which exploit different parts of the marine environment, such as commercial and recreational fishing; aquaculture; sand and gravel mining; oil, gas, and mineral exploration and extraction; channel dredging; dredge material disposal; pipeline/cable installations; and recreational activities. Taken together, the variety of ways in which society utilizes the ocean and its resources make up the "Blue Economy." Our goal of sustainable exploitation of the ocean means we must balance the Blue Economy with stewardship for a healthy environment. The most frequent approach to achieving this balance is through a program of marine spatial planning. Marine spatial planning can reduce use-use and use-environment conflicts, promote efficient use of space and resources, reduce cumulative impacts to the environment, preserve ecosystem services, increase certainty for private sector investments, and improve opportunities for stakeholder engagement (Santos et al. 2019).

However, marine spatial planning requires access to marine geospatial information to make evidence-based decisions. Before any marine spatial planning can take place, decision-makers must understand *where* current and emerging uses of the domain operate and how they function without additional human interference. They must also understand the compatibility of the area with those uses. Then, decision-makers can review that information to better understand where conflicts exist and create a marine spatial plan that integrates users' interests and ideas, a healthy ecosystem, and that reduces and/or solves conflict. Those data may also reveal knowledge gaps where data, information, or knowledge is lacking.

One of the most important places for marine spatial planning initiatives are coastal zones. The world's population is concentrated around the coasts with over 50% living within 50 kilometers of marine waters; even more depend on the coasts for their livelihoods (IHO 2017). In the United States, population density along coasts is five times greater than that of the rest of the nation (OCRM 2007). Marine spatial planning in the coastal zone—and bridging the gap between marine and inland waters—is of utmost importance to maximize benefit from the marine domain without damaging the environment. Government planning authorities and decision-makers often struggle to balance the allocation of coastal space with a plethora of interests, including recreational and commercial fishing, diving, yachting, professional navigation, beach access, tourism activities, and marine farming.

Without evidence-based decision-making, coastal construction and development can result in significant negative impacts on property, people, and the environment. Marine geospatial data in coastal and inland waters can help decision-makers evaluate space and its suitability to support specific interests. For example, groins, jetties, or revetments built along a coast to create a clear channel or safe harbor for fishing boats may result in the erosion of sand downdrift of the structure due to decreased sediment transport and subsequent accretion of sand in other areas. Proper modelling of proposed artificial features along a coast with marine geospatial information can avoid potentially significant economic impacts due to loss of shoreline and beaches. Similarly, with access to marine geospatial data, managers of pipelines, telecommunication cables, and offshore drilling platforms can utilize bathymetric data to ensure their locations are safe from potential hazards.

Access to marine geospatial information can also benefit individual activities in the marine domain. For example, access to existing marine geospatial information can help reduce mineral exploration costs (and increase the efficiency of data collection). As hydrographers characterize the seafloor, they also collect acoustic backscatter. This backscatter can be used to determine the type and extent of different bottom characteristics and, if accessible, can significantly reduce the cost of exploration for private businesses while continuing to improve navigational safety. Bathymetric information can also be helpful and is critical to selection of routes for submarine pipelines and cables. (FIG 2010).

Another activity that can benefit from access to marine geospatial information is commercial fishing. Commercial fishermen can improve their knowledge of preferred fish habitats, locate wrecks and other hazards that might interfere with nets and/or navigation, and improve the speed and efficiency of onload/offload operations with accurate marine geospatial data. Bathymetric data in particular are critical to characterizing and delineating fish habitats.

With access to more marine geospatial information, countries can more effectively and sustainably conduct marine spatial planning and utilize marine resources.

Emergency Management and Response

Marine geospatial information underpins the effective prediction of, response to, and management of many natural and human-generated disasters by providing baseline conditions prior to an event and assisting in timely recovery and relief. Responses to numerous high-profile events in the last ten years have required access to marine geospatial information—large chemical or oil spills like the BP oil spill in the Gulf of Mexico, airline crashes such as Malaysia Airlines flight MH370, increases in harmful algal and seaweed blooms like Sargassum seaweed, and natural disasters including hurricanes, earthquakes, and tsunamis.

Marine geospatial information can provide benefits in all phases of disaster management. Prior to a disaster, marine geospatial information can be used to assess which areas are at greatest risk and most vulnerable to a potential disaster. This allows policy and decision-makers to prioritize areas for mitigation or relief efforts prior to an event which can result in a reduction of impact and costs. During emergency and resiliency planning, and post-disaster activities, marine geospatial information can help manage impacts in real-time or near real-time and help recovery efforts prioritize assistance to the areas most affected. Access to marine geospatial information can also help decision-makers monitor recovery or cleanup progress after a disaster has occurred.

Ultimately, swift access to marine geospatial information can mitigate risk and damage and save lives. In one of the case studies discussed in a later section, Norway and Canada integrate data and web services to display ice frequencies in the Arctic. Their ability to share and integrate data quickly could prove useful in the event of an Arctic emergency.

Maritime Limits and Administration of Spaces

The United Nations Convention on the Law of the Sea (UNCLOS) established the basic framework for boundary definitions of Territorial Sea—the Exclusive Economic Zone (EEZ) and the Continental Shelf. These zones determine the rights and responsibilities of coastal states. Coastal nations can extend their claims beyond the 200-mile limits based on bathymetry, slope of the Continental Shelf, and the geology of the seafloor of the Continental Shelf. This makes marine geospatial information an absolute necessity when it comes to defining maritime boundaries and tenure. Agreed-upon boundaries can reduce conflict and allow coastal nations to access submerged lands, providing those nations with marine tenure and the opportunity to grow their Blue Economy.

For example, in 1998 Australia initiated a survey to define the limits of its extended continental shelf. Australia submitted its results to the United Nations and was able to extend its claim by roughly 2.5 million square kilometers. While undertaking the survey proved a significant investment, the marine resources and economic opportunities claimed under that expansion far outweighed the initial costs (FIG 2010).

Law Enforcement and Defence

A variety of threats—people, drug and weapons smuggling, piracy, and illegal fishing—can endanger the economies of coastal nations, which must protect their commerce, marine resources, and residents. Many coastal nations operate their own law enforcement, but those organizations often lack the resources to deal with all the threats operating in their territorial waters and EEZs.

Marine geospatial information can help coastal nations leverage their resources to maintain order and safety. For example, accurate charting can provide law enforcement organizations with the ability to outmaneuver some threats, like piracy or illegal trade, and allow them to prioritize threats when resources are limited. Maintaining free flow of trade improves economic growth by opening the most efficient routes, cutting transportation costs, and minimizing losses incurred through threats like piracy, maritime terrorism, and illegal trade.

Challenges and Solutions

Government agencies, research institutions, the private sector, and other stakeholders have invested considerable time and resources into marine monitoring and observation, data sharing and dissemination, and downstream services. Significant strides have been made in collecting, aggregating, and making marine geospatial data available. However, many initiatives still struggle to unlock the full societal, environmental, and economic potential of the wealth of marine data and observations at local, national, regional, and international levels. The landscape remains highly fragmented and complex, and the need for better integrated and sustained access to marine geospatial information remains high. The ability to effectively share, use, and re-use marine geospatial information across and between diverse groups of stakeholders is dependent upon access to and awareness of marine geospatial data. Based on responses to the use case, outcomes from the Working Group's meetings, and current literature, the Working Group summarizes some of the primary challenges stakeholders face when managing, providing, and utilizing marine geospatial information.

Marine geospatial data collection and management are funded for a purpose with tightly defined responsibilities.

The task and resources needed to collect and manage marine geospatial data are often allocated to one agency, institution, or department. Historically, most marine geospatial data collection and management was tasked to hydrographic offices for the purpose of safe navigation, now, many agencies and other non-government organizations collect, manage, and curate marine geospatial information. However, due to a variety of restrictions, including status as a public sector organization, funding arrangements, and strictly defined goals and objectives, many institutions do not have a mandate in place that prioritizes making marine geospatial information available and accessible. Consequently, those data are never made available and many uses of those data are never realized (such as the use of data to help stakeholders define the bottom characteristics of the seafloor). This results in duplication of effort, economic loss, completely forgone economic opportunities, and/or policy decisions made without relevant geospatial data.

In the use case exercise responses, the Working Group found that many Member States did not manage all the data or data themes necessary to respond to the described crisis. Furthermore, many respondents were unsure which agencies collected and housed needed data and/or what process to complete to request needed data. Some respondents also outlined lengthy data-request procedures for access to another agency's data. These procedures were often prohibitive in that they required time and/or financial resources the respondent could not spare. Additionally, those data requests when submitted, might go unfulfilled or result in unusable data. This disconnect was especially apparent across different levels of government. Federal agencies often had little to no knowledge of what data their state or provincial counterparts collect and manage and vice versa. While there were examples of high-functioning data-sharing partnerships in the responses received, there were far more examples of general unawareness on what data exists and where to find it.

To further complicate matters, agencies and institutions with different organizational missions often used different standards, including for metadata. Varying standards impeded the interoperability of data when shared. Thus, when data were available, they were not accessible in a functional way. Respondents also described discrepancies in or missing metadata that could prohibit stakeholders from discovering and understanding which data might be most useful in the context of the user's need.

The Working Group feels the solution to this challenge lies in establishing data-sharing partnerships and the implementation of internationally agreed-upon standards. Establishing ministry-level agreements (not legislation per se) to mandate data-sharing can give many institutions the justification they need to embark on making their data available. If possible, the Working Group recommends expanding agreements to include neighboring nations and the UN system to take full advantage of available data and data management frameworks. Data-sharing partnerships can exist outside governments as well, and the Working Group highly recommends maintaining relationships with the private sector, academia, and other stakeholders, to increase access to geospatial data and new geospatial technologies.

Most existing geospatial data legislation was developed with other goals in mind.

Many experts see legislative mandates as the solution to challenges in data-sharing, data availability, and data accessibility. However, much of existing geospatial data legislation was developed with other geospatial issues in mind (e.g., cadastre, safe navigation, and/or legal maritime boundaries). Marine geospatial data has many unique qualities, such as the temporal and dynamic nature of the data, that require special consideration. Thus, translating existing geospatial legislation into legislation relevant to the marine domain may not be possible. Additionally, the use of legislation to mandate data-sharing has the potential to backfire as it may encourage agencies currently sharing data to cease data-sharing if the mandate is not explicitly applied to their mission. Rather than creating strict data-sharing legislation, the Working Group recommends adjustments to national policy which emphasize a "collect once, use many times" approach to data collection, access, and management.

The fragmentation of data across domain-specific agencies and difficult technical considerations must be resolved to integrate terrestrial and marine geospatial information.

Perhaps the biggest challenge facing the geospatial community is the integration of geospatial data from the terrestrial and marine domains, including data from inland waters. Terrestrial mapping and nautical charting agencies often developed separately to address different users and issues. Each collects geospatial data for their individual purpose and mission and uses their own technical specifications without consideration for data-sharing or distribution of data to wider communities. This results in silos of data and in information cultures which work against the sharing of multi-disciplinary geospatial information.

In addition to the fragmentation of data across domain-specific agencies, the 'digital divide' that exists between terrestrial and marine data sets also makes their integration a tedious operation. A variety of technical differences must be resolved, such as the definition and delineation of the coastline, incompatibility of data formats, spatial reference systems (horizontal datum, vertical datum, and coordinate system), data accuracies, scale of data source, feature or object definition, resolution or data acquisition method, and data modelling (UN-GGIM 2013 [E/C.20/2013/10/Add.1]). Table 2 below provides a comparative list of typical differences across terrestrial and marine data sets.

Items	Topographic Map	Nautical Chart
Coastline	From aerial photograph (where land and water meet at time of exposure)	High tide water level
Horizontal Datum	Indonesian Datum 1974 (maps published before 1996); WGS 84 (maps published after 1996)	Bessel 1841; WGS 84
Vertical Datum	Mean Sea Level (MSL) for land elevations; no depth information	MSL for land elevations; chart datum for depth information (e.g., low tide water level)
Projection System	Universal Transverse Mercator	Mercator
Digital Storage Format	Various formats (DWG, ARC, SHP)	S57 files
Scale	Systematically scaled (1 to 10K, 25K, 50K, 100K, 250K).	Not systematically scaled (ranges from large to small scale)

Table 2: Technical differences between terrestrial and marine data sets (UN-GGIM 2013).

Integrating geospatial information from inland waters with that from the terrestrial and marine domains presents its own set of unique challenges. Inland waters are typically managed by an entirely different agency (separate from the terrestrial and marine domains) and the management of inland waters is often folded into the mission of multiple agencies. Additionally, agencies collecting and managing geospatial data from inland waters are wholly left out of many discussions on terrestrial and marine data integration, the importance of those data only being realized during a time of need or late in the data management planning process. Based on the use case responses, many Member States felt that their marine geospatial information was not connected to data from inland waters in any meaningful way despite being strongly connected to land and marine resources.

The Working Group feels that the adoption of national and international frameworks (e.g., the IGIF), which emphasize the integration of and data-sharing between all domains, will provide the institutional structure for terrestrial, inland water, and marine data integration and access.

Many nations struggle to balance data-sharing and national security concerns.

Many nations struggle to balance concerns over national security with data-sharing when managing, providing, and utilizing marine geospatial information. For many Member States, navies are the primary source of marine geospatial information and have restrictions on making those data available. However, one of the main barriers defence organizations face when deciding whether to share potentially sensitive data is the lack of clear security policy guidelines (Lachman et al. 2007). Security policy guidelines define the types of and reasons for information sensitivity and provide guidance on how to properly share those data. For example, many defence organizations collect and manage some data that are not sensitive, but because a portion of those data are sensitive, organizations make no attempt to share data at any level. With clear security policy guidelines, those organizations could more easily determine if their data is sensitive, if their data can be shared, and how.

Another barrier that nations and defence organizations face when it comes to sharing data are proprietary concerns. For instance, if a defence organization purchases geospatial data from a private company and wishes to share those data with organizations outside the federal government, e.g., state or county governments or their contractors, they may run into legal issues.

The Working Group feels that these concerns are best overcome by developing a national policy that balances national security with the ability to release non-sensitive information based on explicit security policy guidance. Security policy can include techniques that allow organizations to remove sensitive portions of data or aggregate data to a non-sensitive level (e.g., with detailed bathymetry). Additionally, formal data-sharing partnerships can provide increased transparency and consistency about what data can be made available. The Working Group notes that the UN-GGIM Working Group on Legal and Policy Frameworks for Geospatial Information Management (WG-Legal and Policy) is addressing policy and legal issues regarding the sensitivity of data and national security. The Working Group will collaborate with the WG-Legal and Policy to develop guidance on elements that may be appropriate for a generic security policy to assist Member States in understanding and defining clear security policy guidelines.

Copyright and other proprietary issues still present significant legal challenges to the geospatial community. While the Working Group encourages the use of metadata to communicate ownership and allowable uses of data, it will monitor the work of the WG-Legal and Policy for additional guidance.

Countries lack the resources to collect and/or share data.

Many Member States and their geospatial institutions recognize the benefits of marine geospatial information and data-sharing but cannot spare the funding or hours to initiate data collection and/or data-sharing efforts. Additionally, the skills required for data collection and management and GIS technology prohibit many developing countries from operating strong data management programs (Herold and Sawada 2012).

The Working Group recommends capacity development as a useful tool to aid countries and other stakeholders in collecting, managing, and sharing marine geospatial information. However, the Working Group also recognizes limits on the resources available for capacity development and encourages Member States to focus on the active transfer of knowledge, tools, and techniques that facilitate the effective collection, management, and sharing of marine geospatial information. The Working Group also encourages Member States to focus on making their own marine geospatial information available as this can help countries without data enter the geospatial community by alleviating costs associated with initial data collection.

Marine geospatial information should be fit-for-purpose.

One of the largest concerns expressed by the Working Group was making sure that data are fit-for-purpose. The marine geospatial community is growing rapidly, and data managers cannot anticipate the myriad of ways that stakeholders might use data. Thus, ensuring that data are fit-for-purpose (i.e., interoperable, timely, current, and safe) and defining the responsibility of the individual producer in making sure data are fit-for-purpose remains difficult.

Interoperability is a key component of fit-for-purpose data and of making marine geospatial information truly accessible. In many responses to the use case exercise, data were available, but Member States were unable to integrate multiple data sources due to differences in data collection, management, or standards. Similarly, relevant data were available in premade products, but were not easily accessible for other purposes. Although premade products can be useful, the knowledge they convey can be trapped in a form that is incompatible with tools and systems used by non-marine agencies and other nontraditional stakeholders. Interoperability across data and geospatial agencies is paramount to ensuring data are fit-for-purpose.

Another hurdle to fit-for-purpose data is providing data when and where it is needed. This is especially difficult for marine geospatial information in situations where network access and data storage are limited (e.g., at sea). Providing mariners and other stakeholders with consistent access to marine geospatial information is vital to making data fit-for-purpose.

A third concern on ensuring fit-for-purpose data identified by the Working Group was minimizing "ghost data." Ghost data are still readily available but are no longer maintained or updated. Some ghost data have historical value, but stakeholders should be aware that those data may no longer be relevant or accurate. Data accuracy is especially important in the marine domain where the environment is in constant flux. Ghost data often result when data managers do not consider the lifecycle of data.

Safety is the last prong to fit-for-purpose data. Marine geospatial data are collected with a purpose and are not appropriate for every use. For example, data collected for scientific purposes may not be safe for navigation. Clearly communicating the original purpose for data can decrease the likelihood that stakeholders use it in unsafe ways.

Understanding the individual producers' responsibility when it comes to providing and maintaining access to fit-for-purpose marine geospatial information remains a complex challenge. The Working Group strongly emphasizes the use of internationally agreed upon standards for data and metadata to fulfill this responsibility. Good metadata should communicate the source of the data and how those data have been processed, helping the *user* determine if data are fit-for-purpose. Data managers should keep in mind the users' perspective and that the user may be accustomed to different standards for packaging data and may use different portals to find data. The user may also be unfamiliar with the traditional terminology associated with marine geospatial information (Figure 6). Data managers may need to adjust to effectively connect with users and to communicate their data efficiently. The Working Group also refers Member States to the IGIF for further guidance on individual producer responsibility. Finally, the Working Group suggests that data managers take time to consider the entire lifecycle of data, including how they might maintain funding for data and its management to minimize the promulgation of out-of-date ghost data.

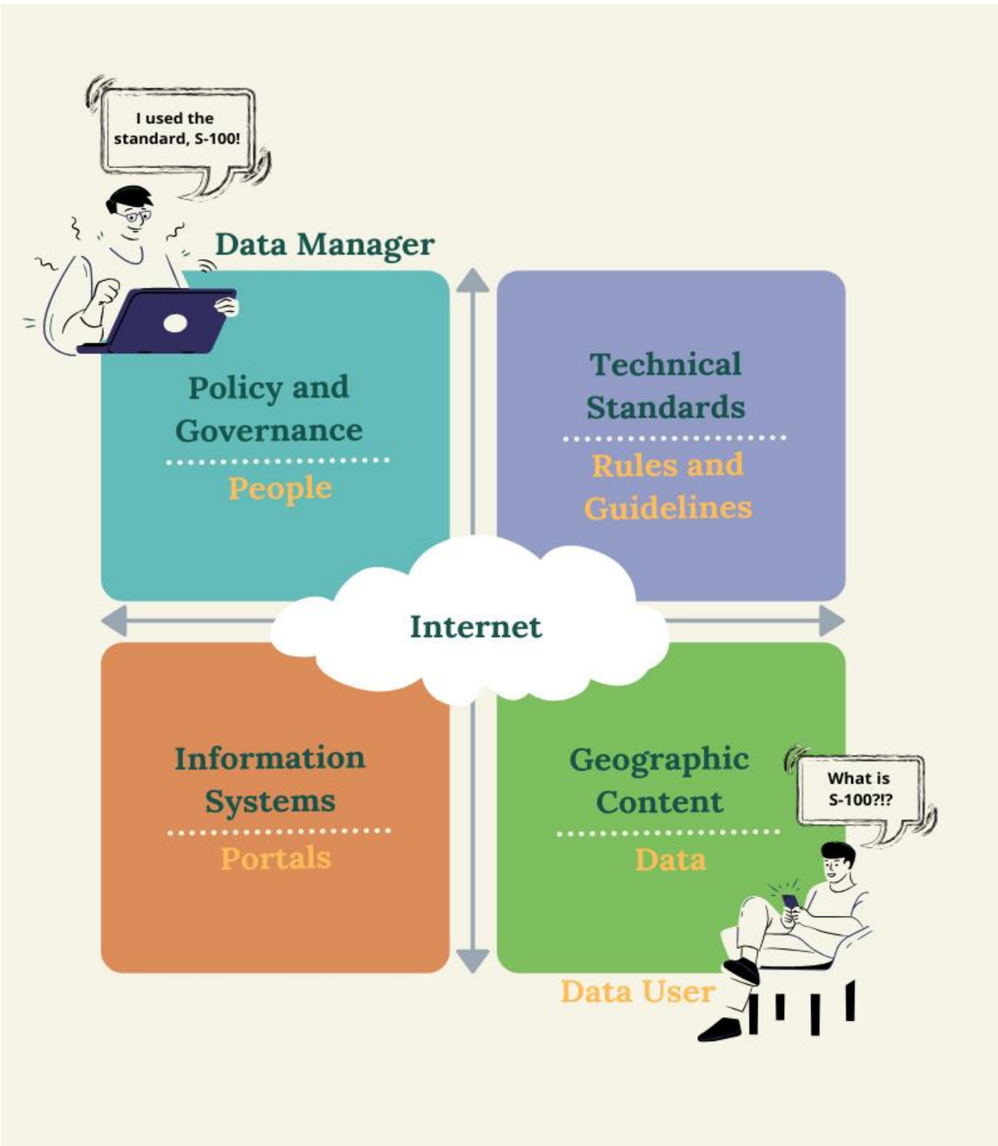

Figure 6: This figure shows the four pillars of spatial data infrastructure: policy and governance, technical standards, information systems, and geographic content (IHO 2017). New data users sometimes speak a "different language" than traditional users of marine geospatial information (e.g., mariners) and may not be familiar with the pillars or traditional geospatial terminology. The dashed line in each colored box separates each pillar from how that pillar might be viewed by a data user (in yellow text). For example, while many data managers are familiar with specific technical standards like S-100, the lay-user may not be. The internet continues to increase the distance between data managers and users, further complicating effective communication of data. Data managers will need to consider the data user's perspective to ensure the user can determine if data are fit-for-purpose.

Data Types and Standards

Member States need access to data which adhere to relevant internationally agreed upon standards to unlock the full potential and benefits of marine geospatial information. The need for certain types of data and data standards was heavily emphasized in the responses the Working Group received to the use case. Consequently, the Working Group felt that a list of important, commonly referenced data types would be helpful to Member States trying to decide what data to make available. While the discussion is not exhaustive, the Working Group hopes that providing these data types will give Member States a starting point. The Working Group also discusses some of the most accepted and internationally agreed upon marine geospatial data standards.

Data Types

The data types in the following list have been included based on information from the use case, from Working Group meetings, from IHO publications, and from the recently published Open Geospatial Consortium (OGC) Concept Development Study (CDS) (OGC 2019). Some data types may overlap with one another. Table 3 provides examples of maritime activities which benefit from data included in the data types described below (FIG 2010).

Hydrographic Data relates to the measurement and description of the physical features of oceans, seas, coastal areas, lakes, and rivers within a given country or region. This typically includes seabed topography (bathymetry), marine infrastructure (e.g., offshore installations, pipelines, and cables), hazards (e.g., wrecks, rocks, and obstructions), aids to navigation, administrative and legal boundaries, areas of conservation, and marine habitats. Member States should also consider crowdsourced hydrographic data collected by the shipping industry, cruise ships, and other stakeholders.

Oceanographic Data includes data on ocean currents, waves, and tides; water properties, such as water temperature, salinity, fluorescence, turbidity, dissolved oxygen, chlorophyll, and suspended material; geology, offshore minerals, and oceanographic features; and sea ice and iceberg presence, density, and velocity.

Land and Coast Data includes topographic base maps and coastal mapping; land cover, offshore cadaster, land ownership, flood hazards, and gazetteer; and optical and radar imagery. This data type may also include historic imagery to provide insight on land changes and near real-time imagery to monitor an area or region.

Vessel Tracking Data includes continual, near real-time monitoring of traffic via Automatic Identification System or remote sensing and historical data on vessel voyages. Data should include vessel position, velocity, voyage, and historical track and position information.

Port Data and Information including information on navigation, hazards, and vessel approach.

Meteorology and Climate Data such as wind velocity and direction, air temperature, humidity, and atmospheric pressure, as well as other climate parameters and indices.

Cryosphere Data such as areas of snow, ice, and frozen ground to support research on warming permafrost, reduction in snow cover extent and duration, reduction in summer sea ice, increased loss of glaciers and the break-up of ice shelves.

Historical Data such as data used for marine spatial planning (MSP).

Real-time Sensor Data includes data received in real-time from marine sensor systems.

Crowd-Sourced Data refers to real-time, georeferenced data collected by citizens or other stakeholders.

Data Standards

The Working Group identified three main standards bodies: The International Hydrographic Organization (IHO), International Organization for Standardization (ISO), and the Open Geospatial Consortium (OGC). These organizations frequently work together to provide standards that complement one another and that can be used in tandem in the marine geospatial community.

The International Hydrographic Organization (IHO) is a domain-specific, intergovernmental organization which promotes uniformity in nautical charts and documents. The IHO began with stand-alone standards, such as the IHO Transfer Standard for Digital Hydrographic Data S-57, but now works to integrate its standards with the ISO Geographic information/Geomatics standards (i.e., ISO/TC 211). The IHO published the Universal Hydrographic Data Model (S-100) standard, which uses and extends the ISO 19100 series of geographic standards for hydrographic, maritime, and related issues. The IHO has published and is developing several other product specifications based on the S-100. These include S-101 Electronic Nautical Chart (ENC) Product Specification (replacing S-57), S-102 Bathymetric Surface Product Specification, S-111 Surface Current Product Specification, S-121 Maritime Limits and Boundaries, and S-122 Marine Protected Areas (MPAs). While these recent standards complement ISO and OGC standards, the transition to the new S-100 is still in progress, and much of the current hydrographic data is still managed to S-57, which is only partially compatible with many of the ISO and OGC standards for Web Services.

The International Organization for Standardization (ISO) Technical Committee on Geographic Information, TC211, has developed numerous standards for geographic information. Many of its standards are abstract, high-level reference models, which are intended to be guidance upon which other domain groups, such as IHO, can develop more specific profiles and product specifications. Importantly, ISO

	Depth	Sea Bottom	Tides, Levels, and Datum	Currents	Coastline	Coordinates	Geographic Description	Limits	Navigational Aids	Wrecks
Aquaculture	X	X	X	X	X	X		X		
Cable / Pipe Laying	X	X	X	X	X	X	X	X		X
Coastal Zone Management	X	X	X	X	X	X	X	X	X	
Defence	X	X	X	X	X	X	X	X	X	X
Dumping	X		X	X		X	X	X		
Coastal Engineering	X	X	X	X	X	X	X	X		X
Environment	X	X	X	X	X	X	X	X		
Fisheries / Living Resources	X	X	X	X	X	X	X	X	X	X
Health / Red Tides	X		X	X	X	X	X	X	X	
Marine Delimitation	X	X	X		X	X	X	X		
Marine Scientific Research	X	X	X	X	X	X	X	X	X	X
Maritime Transport / Navigation	X	X	X	X	X	X	X	X	X	X
Natural Hazard / Modeling	X	X	X	X	X	X	X		X	
Non-living Resources	X	X	X	X	X	X	X	X		X
Ports	X	X	X	X	X	X	X	X	X	X
Real Estate	X		X	X	X	X	X	X		
Safety of Life at Sea	X			X	X	X	X	X	X	X
Sports	X	X	X	X	X	X	X	X	X	X
Tourism	X		X	X	X	X	X	X	X	X

Table 3: A list of maritime activities that can benefit from various types of marine geospatial information (FIG 2010).

standards are widely accepted and adopted, such as the general feature model, metadata, spatial referencing, spatial schema, coverage geometry and register standards. These standards form the basis of the IHO S-100 standard.

The ISO also created standards to support Web Services. The ISO defines the encodings used in Web Services, Extensible Markup Language (XML) and Geography Markup Language (GML). Geography Markup Language is the namespace for geographic information in XML and is an XML grammar defined by the Open Geospatial Consortium (OGC). The GML has also been identified by ISO as standard ISO 19136 Geographic information—Geography Markup Language. The ISO and the OGC have defined other standards for Web Services as well.

The Open Geospatial Consortium (OGC) is an international consortium of more than 500 businesses, government agencies, research organizations, and universities, which develops service standards for Web Services and strives to ensure that geospatial information and services abide by the F.A.I.R. principles (i.e., information and services are findable, accessible, interoperable, and reusable). The group works closely with ISO and IHO to provide implementation-level standards that are used in services. The OGC standards are sufficient to implement a full suite of web services and remain in active development as web services require constant maintenance and evolution. Current OGC Standards used in the marine geospatial community are listed below.

Observations and Measurements (O&M) The general models and XML encodings for observations and measurements.

PUCK Protocol Standard defines a protocol to retrieve a SensorML description, sensor "driver" code, and other information from a device, enabling automatic sensor installation, configuration, and operation.

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

Web Feature Service (WFS) provides an interface to request geographical features across the web using platform-independent calls.

Web Coverage Service (WCS) defines web-based retrieval of multidimensional coverages (i.e., digital geospatial information representing space- or time-varying phenomena).

Catalogue Service supports the ability to publish and search collections of descriptive information (metadata) for data, services, and related information objects. The standard facilitates presentation of search results for evaluation and further processing by humans and software.

Sensor Model Language (SensorML) Standard models and XML Schema for describing the processes within sensor and observation processing systems.

Sensor Observation Service (SOS) Open interface for a web service to obtain observations and sensor and platform descriptions from one or more sensors attached to a platform.

Sensor Planning Service (SPS) An open interface for a web service by which a client can determine the feasibility of collecting data from one or more sensors and can submit collection requests.

Sensor Alert Service (SAS) provides notification of events such as measurements, sensor anomalies, or observation actions.

The development of the next generation of OGC standards is underway. These standards will be designed using an Application Programming Interface (API) approach and will enable greater and simplified use by the web developer community.

Case Studies

Below the Working Group discusses five case studies which demonstrate different ways that Member States have tackled marine geospatial information management. These case studies reveal proven practices that have helped Member States overcome challenges to managing, utilizing, and providing access to marine geospatial information and emphasize the benefits to be gained when data are shared and available.

Arctic Spatial Data Infrastructure and Marine Spatial Data Infrastructure

In 2016, Member States of the IHO Arctic Regional Hydrographic Commission (ARHC) established the Arctic Regional Marine Spatial Data Infrastructure (MSDI) Working Group (ARMSDIWG). The ARMSDIWG is composed of hydrographic office representatives from the various ARHC Member States. The ARHC works towards the implementation of an MSDI for the Arctic. Member States monitor SDI-related activity in the region, consider policies and data contributions of Arctic maritime authorities, and work closely with open standards organizations and related projects, including the Open Geospatial Consortium Marine Domain Working Group and the Arctic Spatial Data Infrastructure (Arctic SDI).

The Arctic SDI is an organization of the eight national mapping agencies of the Arctic operating under a Memorandum of Understanding (MOU). In its first year, the ARMSDIWG coordinated with the Arctic SDI to explore areas of collaboration to strengthen the overall SDI for the region. The Arctic SDI provides a geoportal for working groups of the Arctic Council, but as most representatives in the Arctic SDI come from land mapping agencies, there was a lack of marine geospatial information in Arctic SDI. This prompted cooperation between the Arctic SDI and the ARMSDIWG. Participating Arctic Member States have been able to demonstrate the benefits of cooperation with increased data-sharing capability.

In one ARMSDIWG project, the Group displayed Canadian data on ice frequencies in the Norwegian Marine Geospatial Management tool. Because those data utilized OGC WMS standards, the Group was able to integrate the data quickly (Figure 7). In another project, the Group was able to use the International Bathymetric Chart of the Arctic Ocean (IBCAO), and the General Bathymetric Chart of the Oceans (GEBCO) Sub-Committee on Undersea Feature Names (SCUFN) digital gazetteer within the Arctic SDI geoportal (Figure 8).

In addition to demonstrating the value of implementing marine geospatial standards, both the Arctic SDI and the ARMSDIWG demonstrate the value of data-sharing partnerships absent formal legislation. Each organization works to communicate with one another, with larger, relevant international bodies, and with other geospatial stakeholders without formal legislation that mandates collaboration (Figure 9). The MOU between the eight national mapping agencies of the Arctic is not legally-binding, and participants can contribute as time and resources are available. Ultimately, the collaboration between countries in the Arctic, the Arctic SDI, and the ARMSDIWG can promote sustainable and safe economic development in the Arctic with the region's improved access to marine geospatial information.

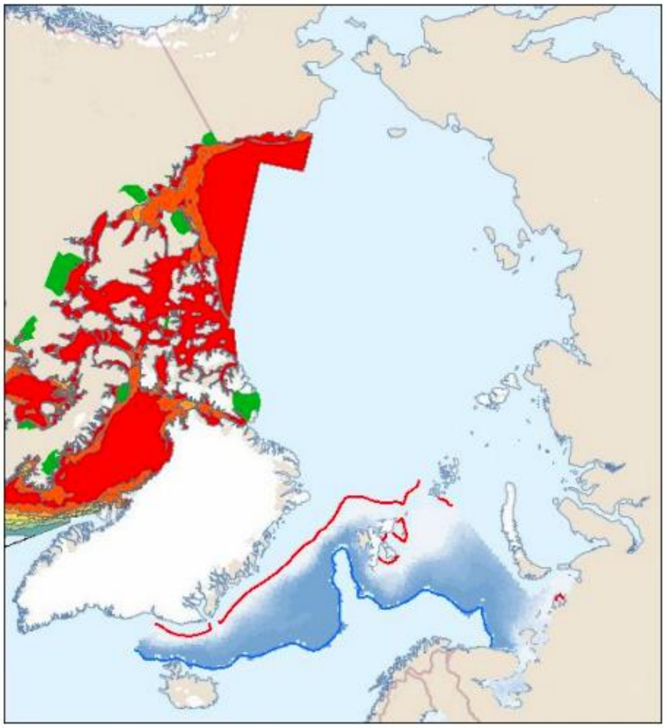

Figure 7: Displaying the Canadian Arctic Voyage Planning Guide (AVPG) web service in the Norway Marine Geospatial Management Tool was facilitated using OGC WMS standards.

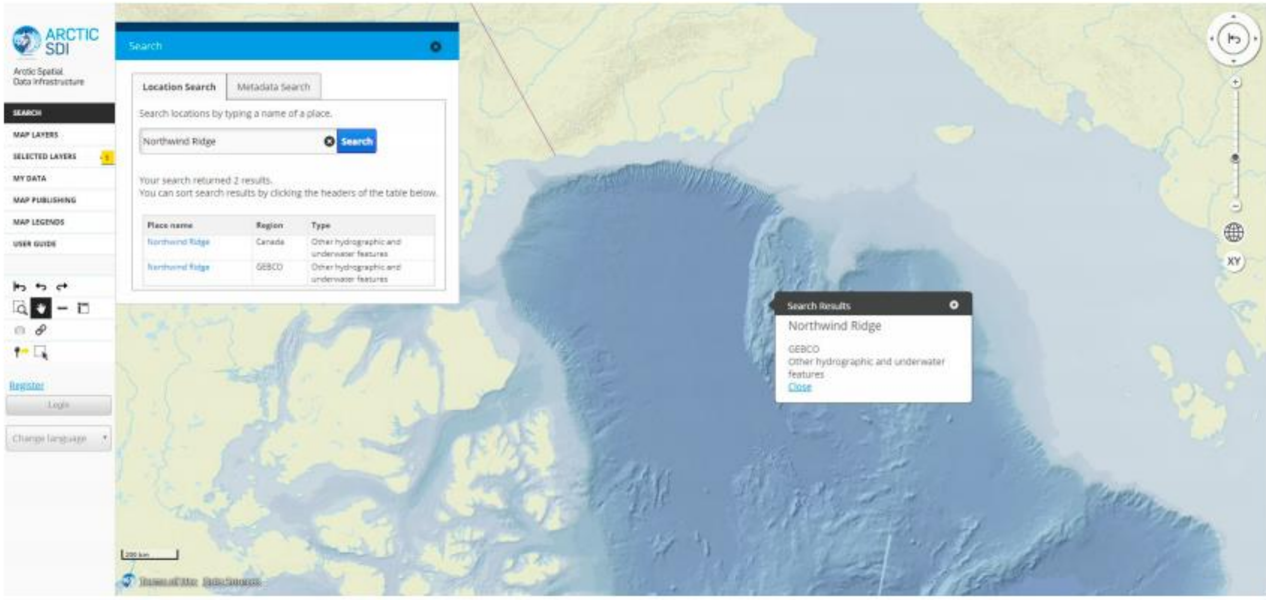

Figure 8: The Arctic SDI Geoportal displaying the Arctic SDI Base map, utilizing the International Bathymetric Chart of the Arctic Ocean (IBCAO) and the GEBCO Sub-Committee on Undersea Feature Names (SCUFN) digital gazetteer service of the names, generic feature type, and geographic position of features on the seafloor.

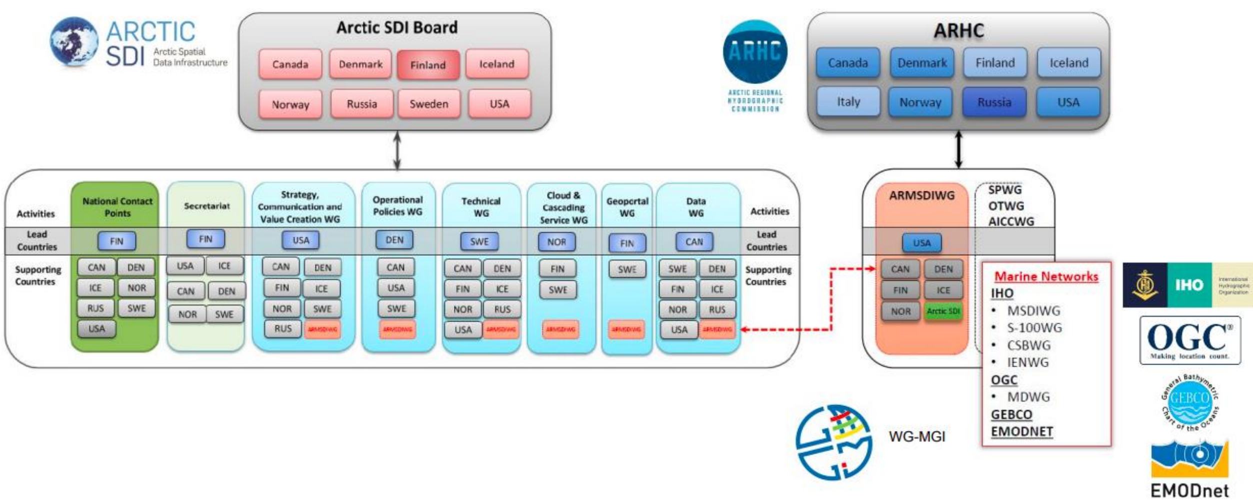

Figure 9: Arctic SDI and ARHC ARMSDIWG Cooperation Structure.

Norway MSDI and MSP

As part of its MSDI, Norway has engaged in Marine Spatial Planning (MSP) for more than 15 years. As the need for marine geospatial information grew, Norway initiated the development of the Norwegian Marine Spatial Management Tool. The goal of the Tool was to support the MSP process with updated and reliable geospatial information. The Tool now utilizes datasets from eleven government agencies and research institutes and standardized network-based services to enable real-time use of geospatial data.

One of the most difficult and resource-intensive challenges Norway faced in developing the Tool was combining different datasets and analyzing them from a user/policy-maker perspective. Norway overcame this challenge by initiating and maintaining dialogue between data providers and owners, data-users, and GIS experts to better understand the data and users' needs and by implementing open data standards and increasing interoperability between datasets.

Thus far, the Tool has been hugely beneficial for improved management of natural marine resources and has allowed Norway to integrate various datasets to improve MSP (Figure 10). The Tool has provided the marine geospatial information necessary to make evidence-based resource management decisions and has increased transparency and involvement in the decision-making process.

Norway's MSDI and Marine Spatial Management Tool provide great examples of how a "collect once, use many times" approach can encourage institutions to prepare their data for increased interoperability and use. Additionally, by formalizing involvement under an MSDI (i.e., establishing a data-sharing partnership), Norway can leverage more of their geospatial resources to make evidence-based decisions on how to utilize their marine resources most effectively and sustainably.

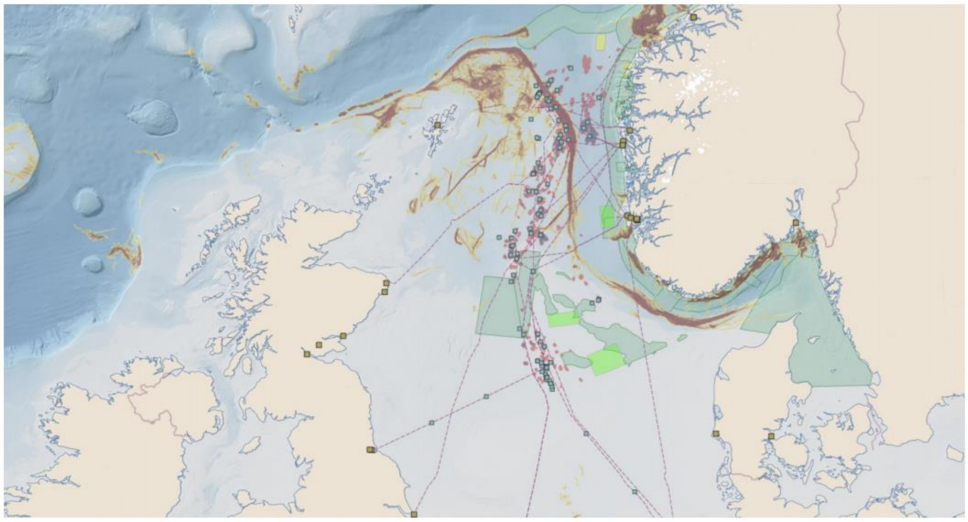

Figure 10: Norwegian Marine Spatial Management Tool displaying bathymetric base map, valuable marine areas (in dark green), commercial fishing (in yellow, orange, and red), petroleum activity (lines and points), and offshore wind assessments (lighter green).

New Zealand's Joining Land and Sea Project (JLAS) and the New Zealand Marine Geospatial Working Group (NZMGI-WG)

The Joining Land and Sea (JLAS) project is a Land Information New Zealand (LINZ) project which will enable geospatial datasets to be merged on a common vertical reference frame (e.g., New Zealand Vertical Datum 2016) (NZVD2016). The project will develop algorithms for an application which will allow users to integrate datasets to seamlessly map across land and sea.

The development phases of the project are:

- update and improve New Zealand's 20-year-old national tidal model;
- constrain the tidal model to land through calibrated tide gauges;
- create gridded surfaces for each tidal level (e.g., MHWS, MSL, LAT); and
- use these gridded tidal surfaces to develop algorithms to enhance LINZ's online coordinate converter tool.

Numerous benefits have been identified for New Zealand from joining land and sea datasets, including improved modelling for sea level rise, flooding, and tsunamis; integrating ocean and coastal mapping; improved shoreline studies and coastal management; and improvements in hydrographic surveying and navigation products.

New Zealand was able to demonstrate the benefit of joining land and sea data after the Kaikoura Earthquakes of 2016 when land and marine Light Detection and Ranging (LiDAR) was integrated to show fault-lines running off-shore (Figure 10).

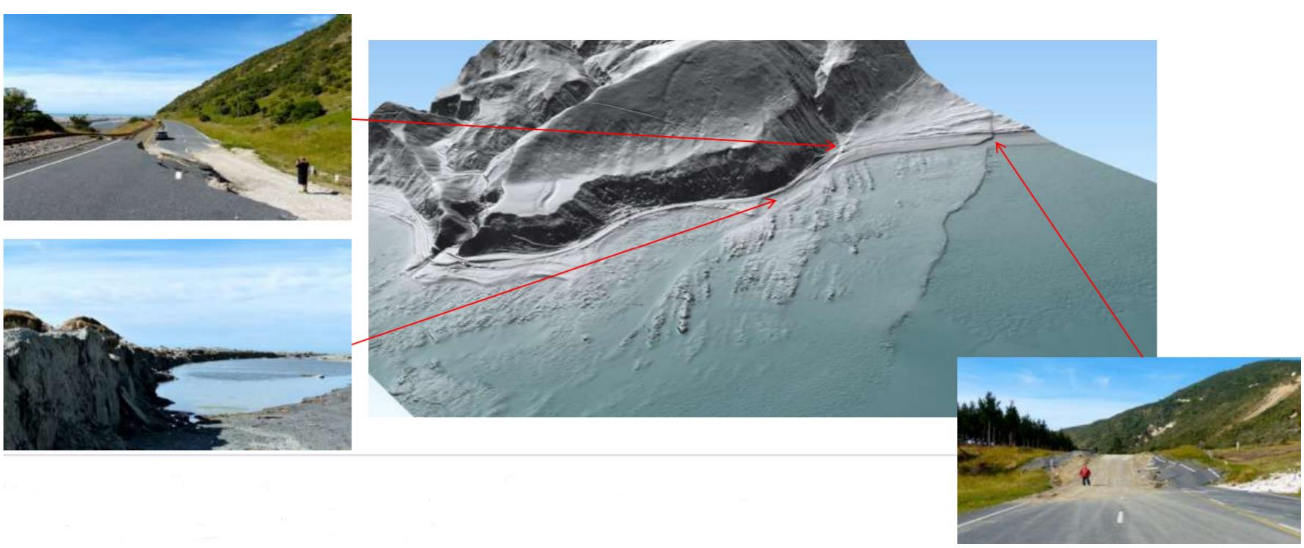

Figure 10: Land and marine LIDAR shows faults breaks running offshore in New Zealand.

LINZ is also responsible for leading and coordinating the New Zealand marine geospatial community and recently established the NZMGI-WG. The Working Group benefits from the input of over 60 public and private New Zealand organizations working to improve access to and re-use of marine geospatial data and to support a sustainable blue economy (Figure 11). The NZMGI-WG has developed a national work program with the goal of making sure that New Zealand marine geospatial information adheres to the F.A.I.R principle (i.e., findable, accessible, interoperable, and reusable), and the Group is working on collaborations to increase the value of marine geospatial information for New Zealand.

Priority projects for the NZMGI-WG include:

- building a national data inventory of available New Zealand marine geospatial information;
- identifying and agreeing on metadata standards for New Zealand marine geospatial information;
- establishing communication channels for the New Zealand marine geospatial information community; and
- reviewing data portals for discoverability and/or access to New Zealand marine geospatial information.

Figure 11: A New Zealand graphic describing the importance of marine geospatial information to marine policymaking. "A sustainable Blue Economy contributes to economic growth, while preserving the health of marine and coastal ecosystems. Marine geospatial data helps us understand our marine environment, supporting decision-making to ensure our oceans are protected for future generations."

Australia's Pacific Community Islands and Territories Tidal Observation Project

The Pacific Sea Level and Geodetic Monitoring (PSLGM) project operates under the Climate and Oceans Support Program in the Pacific. The project is a continuation of the 20-year South Pacific Sea Level and Climate Monitoring Project (SPSLCMP). The fourteen Pacific Island countries participating in the project include the Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu (Figure 12).

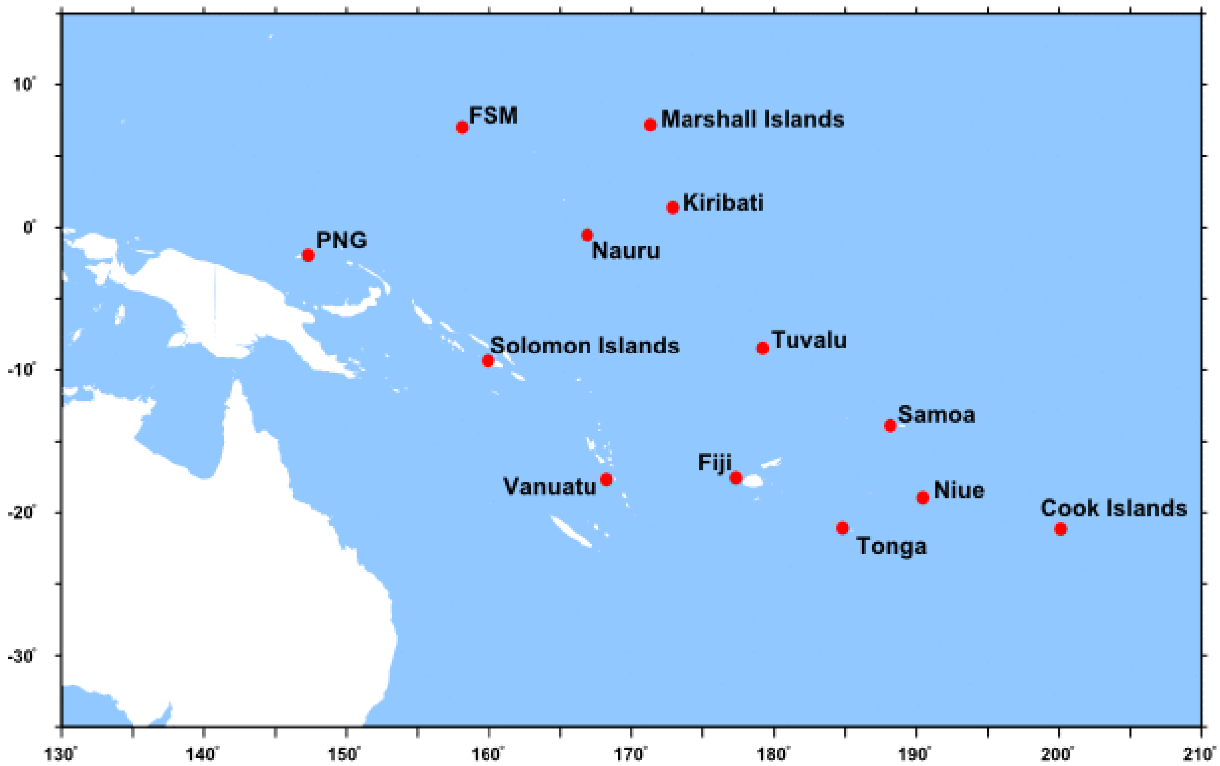

Figure 12: Countries participating in the PSLGM.

The primary goal of the project is to generate an accurate record of variance in long-term sea levels for the Pacific region. The project provides information about the processes, scale, and implications of sea-level rise and variability of extreme events on South Pacific communities. The project makes sea-level data more readily available and usable to support the management of coastal infrastructure and industries.

Ultimately, this data-sharing partnership has increased the capacity of the area and individual countries to respond to changing tides and rising sea levels. Of equal importance, the project has encouraged the development of the marine geospatial community in each of these countries.

GEBCO Seabed 2030

Driven by the desire to provide reliable, authoritative data for policymakers, to use the ocean sustainably, and to improve scientific research, Seabed 2030 was launched in 2017. The project is a collaboration between the Nippon Foundation of Japan and the General Bathymetric Chart of the Oceans (GEBCO; operating under the auspices of its parent organizations—the IHO and the Intergovernmental Oceanographic Commission (IOC) of the UN Educational, Scientific and Cultural Organization (UNESCO)). The project aims to integrate all available bathymetric data to produce a definitive, high-resolution map of the entire world ocean floor by 2030 and to make that map available to all. The project is aligned with the UN's Sustainable Development Goal 14, to conserve and sustainably use the oceans, seas, and marine resources.

Traditional bathymetric mapping techniques rely on acoustic mapping technologies deployed from the surface or submerged vessels. Given the size of the world's ocean and its unmapped portions, it would take many actors to map all the seafloor with existing, traditional technology. Thus, Seabed 2030 recognizes that the only way to meet their goal is through international collaboration on data acquisition, assimilation, and compilation. Their strategy is the creation of Regional Data Assembly and Coordination Centers (RDACCs) that are responsible for specific ocean areas. The centers are responsible for identifying existing data, collaborating with existing mapping efforts, and coordinating new mapping efforts. In addition to these efforts, Seabed 2030 is augmenting traditional mapping techniques with crowd-sourced bathymetry to speed up data collection. The project is orchestrated by a largely voluntary community of international scientists and hydrographers collaborating with the GEBCO Guiding Committee.

The Seabed 2030 project to provide a definitive map of the ocean floor has global benefits. The Seabed 2030 project demonstrates the power of promoting awareness, data-sharing partnerships, and encourages awareness and use of standards and good metadata. Beyond the awareness raised and partnerships established during the project, bathymetric data and understanding the shape of the seabed is fundamental to managing many of the larger, societal, and environmental issues the world must face. Bathymetric data can improve understanding of ocean current circulation (an important driver of climate and climate change); forecasting of tsunami wave propagation and other dynamic phenomena, such as sediment transportation, wave action, and underwater hazards; safety of navigation, both surface and sub-surface; and understanding of the marine habitats and ecosystems vital to safeguarding the planet. Ultimately, the project will likely strengthen the relevance of and support for the entire geospatial community.

Recommendations

While the Working Group makes many suggestions throughout this paper, the Working Group's main recommendations are summarized below.

1. Develop data-sharing partnerships to facilitate the timely sharing of data between Member States, government agencies, research and academia, private data-providers, and other stakeholders.

Legislation can facilitate data-sharing partnerships, but the Working Group suggests using legislation sparingly to avoid situations where legislation encourage agencies currently sharing data to cease if the mandate is not explicitly applied to their mission. Establishing ministry-level agreements (not legislation per se) to mandate data-sharing can give many institutions the justification they need to embark on making their data available. If possible, the Working Group recommends expanding agreements to include neighboring nations and the UN system to take full advantage of available data and data management frameworks. Data-sharing partnerships can exist outside governments as well, and the Working Group highly recommends maintaining relationships with the private sector, academia, and other stakeholders, to increase access to geospatial data and new geospatial technologies. Developing data-sharing partnerships also aligns with the goals of larger, global frameworks like IGIF and FELA (Figures 2 and 3 respectively), which focus on national and international data-sharing partnerships.

2. Implement internationally agreed-upon standards, including standards for metadata to make data-sharing easier and to make data more discoverable (e.g., ISO, IHO, and OGC standards).

As demonstrated in several of the case studies, standards greatly increase the interoperability of data. Widely accepted and adopted standards like those described in this paper make a huge difference in the time and resources needed to integrate and use data. Additionally, increasing the interoperability of data can increase its value and provide economic benefits to the collecting and managing institution. The IGIF and FELA emphasize the use of internationally agreed upon standards specifically to promote interoperability and integration of data.

3. Collect and manage marine geospatial information with multi-use purposes in mind and increase stakeholder awareness of what information is available and where.

Using a "collect once, use many times" approach can help all stakeholders become "fully engaged in the value" of marine geospatial data. Adjusting national policy to frame this approach can give many governmental and non-governmental organizations the justification they need to make their data available for other uses. A multi-use approach, with intention to share, can increase the value of geospatial data. The Group also emphasizes the importance of outreach and awareness as data are only multi-use if users are aware of the data and where it is available. Maintaining standardized metadata can increase the discoverability of data and help users determine if the data are fit for their purpose.

4. Participate in capacity development opportunities when resources allow and actively transfer knowledge, tools, and techniques that facilitate the collection, management, and sharing of marine geospatial information to developing counterparts.

UN frameworks, like IGIF and FELA, stress capacity and capability development and education. The Working Group recognizes that capacity development is a useful tool to aid countries and other stakeholders in collecting and managing their marine geospatial information. However, the Working Group also recognizes limits on the resources available for capacity development and encourages Member States to focus on the active transfer of knowledge of tools and techniques that facilitate the effective collection, management, and sharing of marine geospatial information. The Working Group also encourages Member States to focus on making their own marine geospatial information available as this can help countries without data enter the geospatial community by alleviating costs associated with initial data collection.

Conclusion

Access to marine geospatial information will play a critical role in the global response to the societal and environmental issues the world currently faces. As the cases studies demonstrate, knowing ***where*** people, marine life, events, and activities are, and their spatial relationships to one another, is essential for informed policy- and decision-making. Real-time geospatial information is needed to prepare for and respond to natural disasters and crises, and to help governments make data-driven, evidence-based decisions, develop strategic priorities, and measure and monitor outcomes.

Contributing to the availability and accessibility of comprehensive location-based information will benefit many users and sectors within the marine domain, including commercial shipping and safe navigation; management of marine resources, the Blue Economy, and marine spatial planning; emergency management and response; maritime limits and administration of spaces; and law enforcement and defence. Geospatial information will play a vital role in addressing issues, challenges, and opportunities in oceans and seas, coastal zones, deltas and tributaries, inland waters and water bodies, and in supporting national development and strategic priorities and the implementation of the 2030 Agenda for Sustainable Development.

The Working Group strongly encourages Member States to consider its recommendations and make strides towards establishing data-sharing partnerships, implementing data and metadata standards, approaching data collection and management with multi-use in mind, and to participate in capacity development opportunities when possible. The marine geospatial community will undoubtedly face many other challenges in managing and providing access to marine geospatial information—legal considerations are of particular note—but the community should take this unique opportunity to embrace its role in the larger geospatial community and in ensuring global sustainability. Data collectors, managers, and providers must promote awareness and understanding of their data to grow the geospatial community and the value of geospatial information.

The largest challenge moving forward is the integration of terrestrial and marine geospatial data. This integration is a priority for many Member States across the globe. Policy-willingness and people-readiness are vital to ensure that institutions collaborate and together consider, develop, and build interoperable standards, frameworks, and infrastructures for the integration of land and marine geospatial information. Perhaps the most helpful next step is the development of an integrated policy and operational framework to facilitate rapid acceptance, qualification, ingestion, and use of relevant marine geospatial information from a range of providers (e.g., government, commercial providers, and citizens) that implements the United Nations Integrated Geospatial Information Framework, and which complements the Framework developed by the Expert Group on Land Administration and Management (i.e., the Framework for Effective Land Administration).

The Working Group hopes that this whitepaper provides helpful guidance on actions countries can take to enhance the availability and accessibility of marine geospatial information towards its widest and fullest utility for the benefits of society, environment, and economy.

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