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A Proposed Institutional and Technical Model for Establishing a Marine Information System in Türkiye's Marine Area Management

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Abstract: The lack of comprehensive and standardized spatial data, which is the most fundamental requirement for the effective management and sustainable use of marine areas, complicates the processes of planning, implementation and monitoring in these areas. Today, institutions responsible for marine areas produce spatial data of varying characteristics in line with their respective areas of responsibility and objectives. However, the production of these data in different standards and formats, lacking inter-institutional coordination, brings with it "interoperability" issues in terms of data sharing and integrated use. Although efforts to establish a National Spatial Data Infrastructure in Türkiye began a quarter of a century ago, a comprehensive information system covering spatial data for coastal and marine areas has not been established. Based on this deficiency, the study addresses the establishment of a "Marine Spatial Data Infrastructure" – in other words, a Marine Information System – compatible with international data standards as an inevitable necessity for the effective management of Türkiye's marine areas. Within the scope of this study, the literature on marine information systems was reviewed, and the application models of competent countries and organizations (National Oceanic and Atmospheric Administration, Australian Marine Spatial Information System, Marine Data Infrastructure Germany, etc.) were examined. Furthermore, a comprehensive analysis was conducted to determine the institutional structure responsible for the marine information system that can manage Türkiye-specific conditions, considering national and international legal regulations and global practices. As a result of the study, the fundamental data classes and data types that should be included in the initial phase of the Türkiye Marine Information System were identified, and a proposal was developed regarding the competent authority responsible for system governance. This study provides an institutional and technical roadmap that will contribute to the data-driven and spatial management of Türkiye's rights and interests within its maritime jurisdiction areas.

Keywords: Marine information system, Marine cadastre, Marine spatial data infrastructure, Turkish national geographical information system (TUCBS), Data standards.

Introduction

Throughout human history, while significant effort and resources have been devoted to the effective management of terrestrial areas, marine areas have been given a lower priority (Akdeniz & İnam, 2024). However, it is increasingly recognized today that a nation's interests are not limited solely to the land-sea interface the homeland does not consist solely of a piece of land but rather possesses a holistic structure composed of land, sea, and air elements (Akdeniz & Inam, 2025b). Today, many activities such as trade, transportation, fishing, mining, communication, defense, and security are carried out extensively in marine areas. Given the diversity of activities in marine areas and the wide range of spatial data they require, Marine Spatial Data Infrastructure (MSDI) is seen as an indispensable component of the Marine Information System (MIS), which enables the production, sharing, and updating of data (Zamzuri & Hassan, 2021).

Institutions and organizations responsible for the use and management of marine areas produce spatial data of various characteristics in line with their own objectives. However, since these data are produced in different standards, various scales, and diverse formats—devoid of inter-institutional coordination—they bring about 'interoperability' problems regarding data sharing and integrated use. Furthermore, this leads to the redundant production of the same data by different institutions and organizations, resulting in both financial costs and time loss. For the effective administration of such a complex and multi-layered structure, there is a need for a systematic data management system that is compatible with international data standards.

Geographic Information Systems (GIS) have become a powerful tool widely used across disciplines thanks to their capabilities for managing, storing, analyzing, and visualizing spatial and non-spatial data (Kızılelma et al., 2017). In this context, GIS have become a fundamental element in the management of information societies and the development of countries (Doğruluk et al., 2024). Accordingly, it is essential to establish a unified and holistic platform by ensuring cooperation and coordination regarding production, storage, updating, and sharing of marine spatial data at the national level, as well as fostering collaboration between marine spatial data producers and users. In Türkiye, a roadmap for the current and future management of spatial data has been established through the 'National Geographic Information Strategy and Action Plans' prepared within the scope of the Turkish National Geographic Information System (TUCBS). However, as seen in international examples, TUCBS addresses spatial data for coastal and marine areas in a limited manner and focuses predominantly on terrestrial areas.

Spatial data infrastructures have become highly developed worldwide today. However, most of these focus on 'terrestrial-based spatial data' and rarely include 'spatial data related to marine areas' (Strain et al., 2006). In many countries, the collection and utilization of spatial data for marine areas are not sufficiently coordinated. The issue of which data should be included in an information system for marine areas is still a subject of debate (Akdeniz & İnam, 2025a). Similarly, the spatial data regarding Türkiye's marine areas are considered an incomplete component of the national information system (Erbaş, 2018).

Marine areas are highly diverse in terms of living and non-living resources and the impacts resulting from human activities. This diversity becomes even more complex and dynamic when the temporal dimension is considered. The effective management of the complexity of natural and artificial processes in marine areas, and the resulting spatial and temporal changes, depends on the collection of spatial data and the mapping of the spatial and temporal distribution and intensity of significant human activities. In this context, one of the objectives of the Turkish National Marine Research Strategy has been determined as 'the development of a national marine data and information management system and the establishment of a data/information sharing network.

Accordingly, there is an increasing and urgent need for the development of a Marine Spatial Data Infrastructure (MSDI), in other words, a Marine Information System (MIS), specific to marine areas. This system aims to establish a management and registration mechanism in marine areas by adapting traditional land information system concepts to the marine context. According to the International Hydrographic Organization (IHO), MSDI is defined as a spatial data infrastructure component that includes both spatial and non-spatial marine information (IHO, 2020). These include marine morphology (bathymetry), geology, infrastructure (wrecks, offshore facilities, pipelines, cables), superstructures (ports, aquaculture facilities, renewable energy plants), administrative and legal boundaries, protected areas, habitats, and oceanographic data.

It is observed that many countries that have made significant progress in the effective management of coastal and marine areas have established their own MSDI and MIS. At the national level, several countries operate their own MIS, such as the Australian Marine Spatial Information System (AMSIS) in Australia, Land Information New Zealand (LINZ) in New Zealand, the Marine Cadastre National Viewer in the United States, the Coastal and Ocean Information Network Atlantic (COINAtlantic) in Canada, the Marine Data Infrastructure Germany (MDI-DE) in Germany, Service Hydrographique et Océanographique de la Marine (SHOM) in France, the Marine Information System (Det Marine Danmarkskat) in Denmark, and the Land and Spatial Planning Agency (MAA-JA RUUMIAMET) in Estonia. At the international level, there are also MIS platforms encompassing the maritime jurisdiction areas of multiple countries. On a European scale, systems such as the European Marine Observation and Data Network (EMODnet) and SeaDataNet for the Adriatic and Ionian Region provide platforms containing data specific to marine areas. In Türkiye, although efforts to establish a National Spatial Data Infrastructure (NSDI) began a quarter-century ago, a holistic information system that sufficiently covers spatial data for coastal and marine areas has not yet been established.

Seas hold vital importance for Türkiye in terms of its geographical location, strategic objectives, and economic value. While Türkiye has a terrestrial area of 783,562 km^2, its maritime jurisdiction areas—either declared or likely to be declared within the framework of the 'Blue Homeland' (Mavi Vatan)—cover a marine area of approximately 462,000 km^2 (Yaycı, 2022). More than 55% of the country's population resides in 28 coastal provinces (Akdeniz & İnam, 2025b). Approximately 79% of the export volume and 93% of the import volume are carried out via maritime routes (Denizcilik Genel Müdürlüğü, 2023). Being surrounded on three sides by seas with different characteristics and production potentials, the fishery production sector is the fastest growing within the entire agricultural production sector (Denizcilik Genel Müdürlüğü, 2023). Türkiye ranks 16th globally in the aquaculture sector (TEPGE, 2025). Furthermore, it possesses significant potential in the marine tourism sector due to its climatic features and natural beauty. Various activities ranging from yacht tourism to diving tourism, and from cruise tourism to water sports, hold a significant share of 20% within the general tourism sector through the foreign exchange inflow they provide (İMEAK Deniz Ticaret Odası, 2023). Due to its geographical position, Türkiye is situated between developed Western countries in need of energy and natural resources and energy supply regions such as Russia and Middle Eastern countries; consequently, several pipelines (Blue Stream Gas Pipeline, Trans-Anatolian Natural Gas Pipeline, etc.) passing through its marine areas. Additionally, it also has both existing and potential energy resources within its marine areas (Akdeniz & İnam, 2025b). In addition to all these, Türkiye's coastal and marine areas are significant due to their rich biodiversity and natural resources. The total surface area of protected areas in its marine regions constitutes approximately 6% of the country's marine areas (Doğa ve Milli Parklar Genel Müdürlüğü, 2022). For a country like Türkiye, which has significant potential in the economic, ecological, and strategic resources of the sea, the subjects of 'MSDI and MIS' are of paramount importance. In this context, the establishment of a 'Marine Spatial Data Infrastructure and Marine Information System' compliant with international data standards for Türkiye's marine area management is considered an inevitable necessity.This study aims to identify the fundamental data classes and data types that should be included in the Turkish Marine Information System. It also seeks to determine the authorized institution responsible for managing the system.

Method

The methodology followed in this study is based on a stepwise approach ranging from conceptual framework analysis to model development. In the first phase of the research, the current international status was determined by examining the Infrastructure for Spatial Information in Europe (INSPIRE) framework. Subsequently, the national context was identified by analyzing data themes for coastal and marine areas within the components of the Turkish National Geographic Information System (TUCBS), along with the data types defined in these themes. In the third stage, internationally recognized application models such as NOAA Marine Cadastre, AMSIS, MDI-DE, SHOM, EMODnet, and the Mid-Atlantic Ocean Data Portal were analyzed, and their data classes and data types were comparatively evaluated. As a result of these comprehensive analyses, the fundamental data classes and data types that should be included in the initial phase of the Turkish Marine Information System were identified. In the final stage, a strategic analysis was conducted to determine the institutional structure responsible for the marine information system, taking into account Türkiye’s specific conditions, as well as national and international legal frameworks and global practices.

Results and Discussion

INSPIRE

The 34 data themes defined under INSPIRE constitute the technical infrastructure of a standardized framework for marine data across Europe. Based on the detailed content analysis conducted in this study, data models directly and indirectly related to coastal and marine areas have been identified; the sufficiency of these models from the perspective of a 'marine information system' has been scrutinized. The analyses indicate that it has been determined that the data types directly related to coastal and marine areas are primarily organized under the *'Oceanographic Geographical Features (OF)'* and *'Sea Regions (SR)'* themes, which are included in the Annex III list.

'Oceanographic Geographical Features' data theme aims to represent the physicochemical state of the seas in a digital environment. Through observation points and grid-based data models, this theme enables the representation of dynamic parameters such as sea temperature, salinity, current velocity, wave height, and optical properties.

'Sea Regions' data theme covers the geographical and physical boundaries of marine areas (coastline, territorial waters, exclusive economic zone, etc.). While this theme allows for the classification of seas in a hierarchical structure (sea, ocean, sub-basin), it remains limited to the spatial representation of predominantly static geographical boundaries. However, it has been determined that these two themes are not sufficient to meet the needs of all stakeholders regarding the use and management of marine areas.

TUCBS

TUCBS, carried out within the scope of the 'e-Transformation Türkiye Project', is a national-level project aimed at establishing a national spatial data infrastructure in Türkiye. TUCBS is an e-Government initiative that aims to establish a geographic information system infrastructure in compliance with INSPIRE directives. It also seeks to define geographic data standards, assign data responsibilities, ensure that data are produced according to common standards, enable data sharing, and support interoperability at the institutional level. The policies, data standards, and cooperation structures developed within the framework of TUCBS allow Türkiye to manage and share its geographic data more effectively (Aslan, 2025).

Within TUCBS, 32 fundamental geographic data themes have been established based on international standards (such as INSPIRE and Land Administration Domain Model) and by making necessary modifications and customizations specific to Türkiye. The analysis shows that, within TUCBS, data related to coastal and marine areas are defined within different data themes according to their semantic integrity, rather than being gathered under a single data theme. Accordingly, the data themes and the data types defined within these themes for coastal and marine areas in TUCBS have been analyzed and are detailed below.

The *'Marine and Brackish Water Areas'* theme defines concepts such as ‘sea’ and ‘coastline’; it also covers coasts and land/sea boundaries (CBSGM, 2020). Furthermore, this data theme provides a general framework for defining oceanographic features representing sub-sections of marine and brackish water areas as well as their chemical or physical properties (mean sea temperature, mean sea salinity). The Marine and Brackish Water Areas theme provides mechanisms for describing the seabed or sea surface features (CBSGM, 2020). Within the data theme, the following data types related to marine areas have been defined: 'marine area', isobath’, 'marine layer', 'marine contour', 'marine site', 'seabed area', 'sea surface area', 'intertidal area', 'coastline', 'coastline segment', and 'shoreline'.

Within the *'Administrative Units'* theme, it has been determined that maritime jurisdiction areas based on the law of the sea—such as internal waters, territorial waters, contiguous zone, exclusive economic zone (EEZ), and continental shelf—are defined under the 'Marine Administrative Unit' class. This theme defines Türkiye’s maritime boundaries of use with riparian countries regarding marine areas (CBSGM, 2020). Furthermore, within this data theme, the following data types related to marine areas have been defined: 'marine administrative unit', 'marine administrative boundary', 'marine region boundary', 'marine administrative region', and 'baseline'.

It has been determined that the *'Transport Networks'* theme provides an integrated structure for the management of transport networks and details related to rail, road, maritime, and air transport. Regarding marine areas, it facilitates the sharing of data that serves as a basis for transport planning or navigation studies between two points (CBSGM, 2020). Under the 'Water Transport Network' class related to marine areas, the following data types have been defined: 'maritime route', 'lighthouse', 'ferry crossing', 'inland waterway', 'port area', 'port node', 'buoy', 'fairway area', 'restrictions for watercraft', 'water node', and 'waterway link'.

The *'Elevation'* theme aims to define the three-dimensional shape of the Earth's surface in terms of elevation characteristics such as altitude or depth (CBSGM, 2020). Regarding marine areas, it has been determined that this theme defines the morphological structure of the seabed. The *'Hydrography'* theme covers all natural, artificial, static, and flowing objects related to hydrography on the Earth's surface, such as basins, rivers, lakes, and dams (CBSGM, 2020). It has been identified that while this data theme encompasses coastal regions, it does not contain any data types directed toward marine areas. Marine areas have been excluded as they are treated as separate themes (Marine and Brackish Water Areas). Within this data theme, the following data types related to coastal areas have been defined: 'coast', 'coastline', 'coastal structure', 'surface waters', and 'coastal soil type'.

The *'Management, Restriction, and Regulation Zones'* (Public Management Zones) theme covers areas that are generally managed, regulated, or used for reporting at international, European, national, regional, or local levels (CBSGM, 2020). Regarding coastal and marine areas, it has been identified that this theme encompasses special areas for protection or restriction purposes (regulated sea lanes, marine protected areas, coastal zone

management areas, mineral exploration and license areas, etc.). Within this data theme, the following data types for marine areas have been defined: 'management restriction regulation zone', 'environmental impact area code', 'specialized zone type code', 'area management zone code' etc.

It has been determined that the 'Protected Sites' theme defines terrestrial, aquatic, or marine areas under protection status—such as national parks, nature parks, wildlife improvement areas, natural heritage sites, special environmental protection areas, and wetlands (CBSGM, 2020). These areas are managed through legislation and other effective measures to ensure the conservation and continuity of biological and genetic diversity, as well as natural and cultural resources.

A Comparison of International Marine Information Systems

The *'NOAA Marine Cadastre'* marine information system is a comprehensive geographic information system established for managing marine resources, planning energy projects, and developing ecosystem-based management strategies within the maritime jurisdiction areas of the United States. Operated through a partnership between NOAA and the Bureau of Ocean Energy Management (BOEM), this system integrates multi-layered data types—such as maritime jurisdiction areas, oceanography, military training areas, navigation safety, renewable energy sites, and protected habitats—within a single platform. Advocating transparency and data-driven management in decision-support processes, the NOAA Marine Cadastre information system is not merely a mapping tool but also a dynamic 'marine cadastre' data model where rights, responsibilities, and restrictions related to marine areas are defined in detail. It has been identified that this spatial data diversity provided by the system clearly reveals the spatial relationship between different types of marine area uses, as shown in Figure 1.

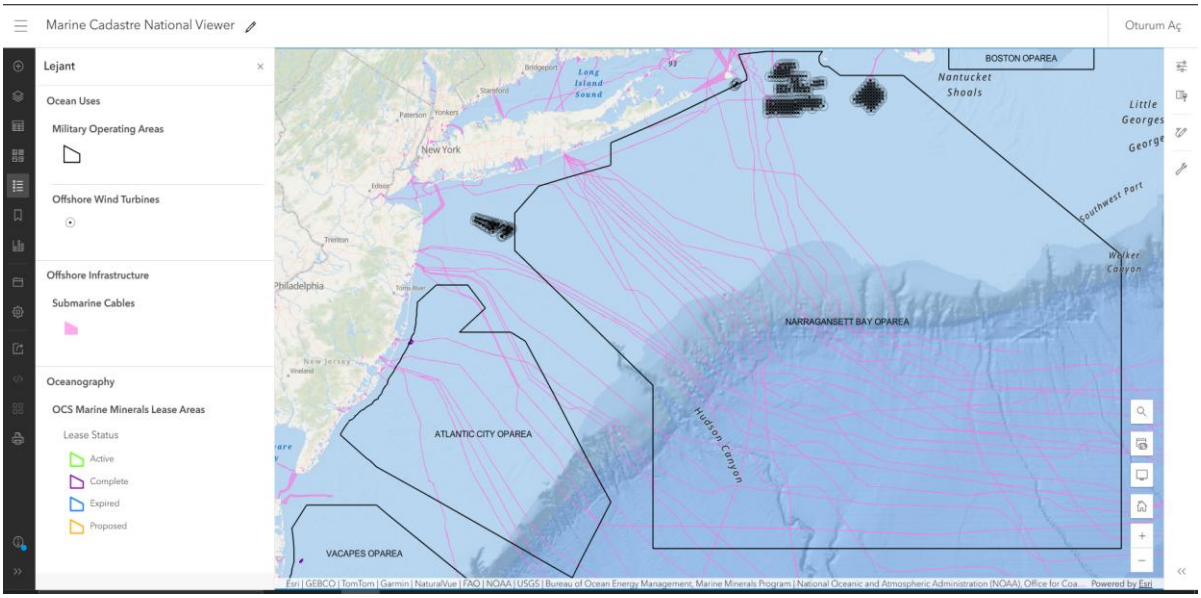

Figure 1. The NOAA Marine Cadastre information system interface and data types

The *'Australian Marine Spatial Information System (AMSIS)'* is an advanced decision-support system managed by Geoscience Australia, which integrates complex and diverse data types across Australia's maritime jurisdiction areas. Structured in accordance with international standards (OGC) and the principles of the law of the sea, the system brings together a wide variety of significant data types, such as maritime jurisdiction areas, submarine cables and pipelines, natural gas and oil exploration sites, fisheries, and marine protected areas. The primary function of AMSIS is to support 'Blue Economy' strategies by associating the maritime jurisdictional boundaries determined in accordance with the United Nations Convention on the Law of the Sea (UNCLOS) with diverse spatial data. In scientific literature, AMSIS is characterized as an exemplary model in marine cadastre and marine information system studies, particularly for its multidisciplinary data management and user-friendly interface that allows various stakeholders (public, private sector, academia, citizens, etc.) to analyze conflicting or overlapping marine use demands on a spatial plane. It has been identified that this data integrity and spatial layer structure provided by the system clearly reveal the spatial relationship between different maritime jurisdiction areas and marine use types, as shown in Figure 2.

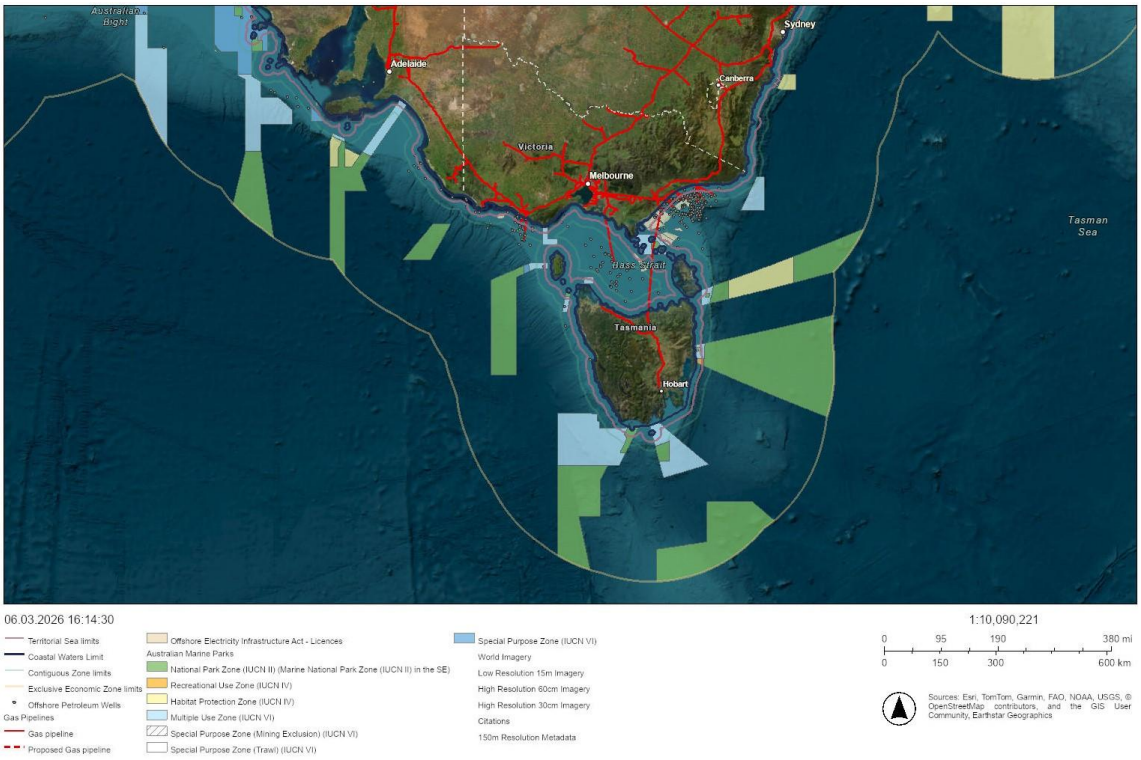

Figure 2. The AMSIS information system interface and data types

The *'Marine Data Infrastructure Germany (MDI-DE)'* is a national spatial information system that supports the management of marine data related to Germany's sovereign waters in the North Sea and the Baltic Sea in a decentralized yet standardized manner. Established through the cooperation of eleven different institutions at both federal and state levels, this system specifically aims to comply with the European Union's Marine Strategy Framework Directive (MSFD) and INSPIRE directives. Technically utilizing international standards such as Web Map Services (WMS) and Web Feature Services (WFS), MDI-DE integrates diverse interdisciplinary data into a single system, including coastal protection, marine geology, oceanography, transportation, marine biodiversity, pollution monitoring, and offshore wind energy planning. The system provides a multi-stakeholder governance model for monitoring complex marine ecosystems. The data integration and interoperability structure provided by the system is illustrated in Figure 3, which includes a section of the portal interface and the types of spatial data provided.

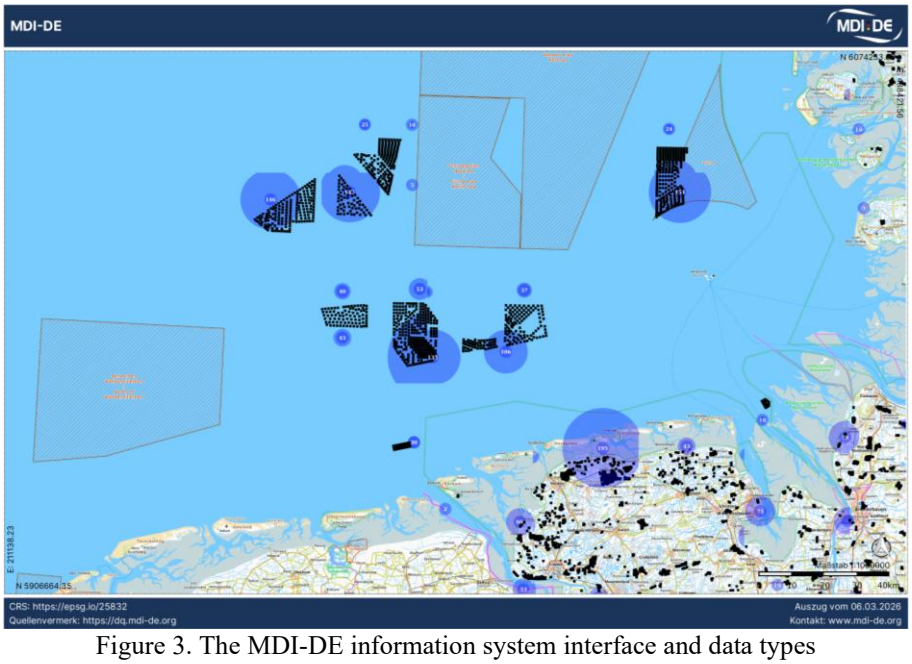

Figure 3. The MDI-DE information system interface and data types

The *'Service Hydrographique et Océanographique de la Marine (SHOM)'*, France's national hydrographic service, is a well-established marine information system that manages the marine spatial data infrastructure and integrates a wide variety of data related to marine areas. Operating under the French Ministry of Defense, SHOM provides data that serve as a foundation not only for traditional nautical charting but also for the determination of maritime jurisdictional boundaries, monitoring of coastal dynamics, military activities, oceanography, and the planning of marine area use activities. The most notable feature of the system is its ability to provide high-resolution bathymetric data, tidal models, and oceanographic parameters in a format compliant with international S-100 standards. With its vision of a 'Pôle de Données Marine' (Marine Data Center), SHOM is considered a spatial management system with high reliability and data precision, making data of military sensitivity available for public benefit and scientific research. It has been determined that this data diversity in French maritime jurisdiction areas and the analysis tools provided by the platform can be followed through the portal interface and bathymetric data sets presented in Figure 4.

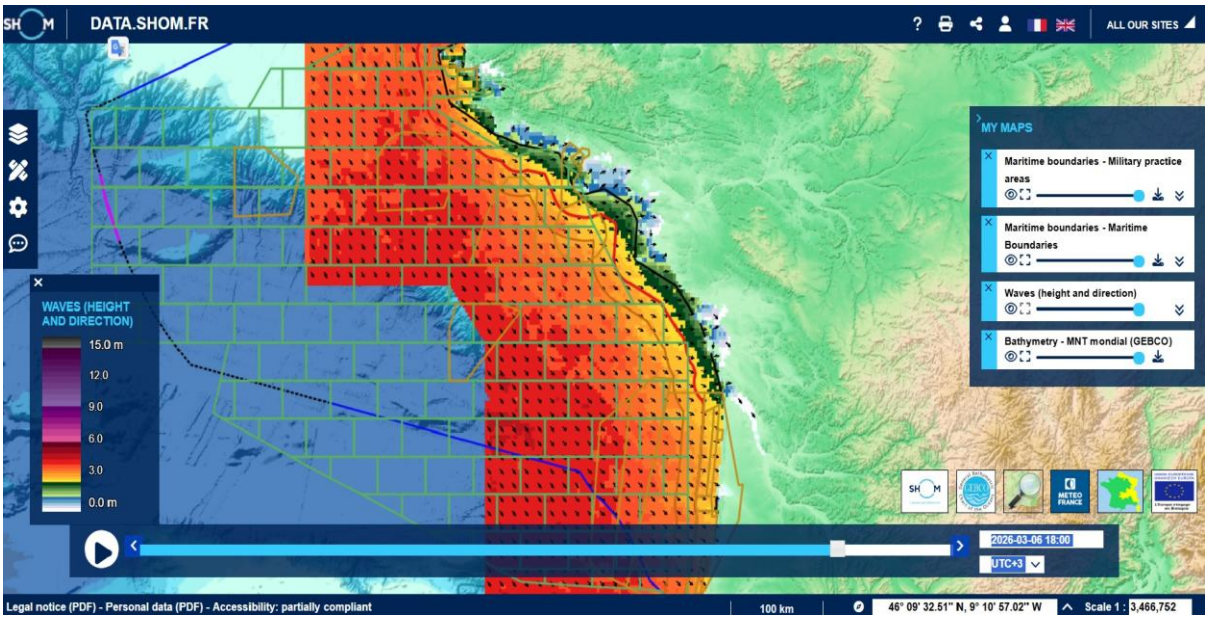

Figure 4. The SHOM information system interface and data types

The *'European Marine Observation and Data Network (EMODnet)'* is one of the most comprehensive marine information systems that consolidates fragmented marine data across the continent into a single point of access, in line with the European Union's 'Blue Growth' and 'Marine Strategy Framework Directive' objectives. Operated through the collaboration of more than 120 institutions, this system establishes data-driven standards in eight main thematic classes: administrative units, bathymetry, biology, chemistry, geology, human activities, physics, and seabed habitats. EMODnet's core philosophy, the 'collect once, use many times' principle, is built upon INSPIRE standards and FAIR (Findable, Accessible, Interoperable, and Reusable) data principles to ensure the interoperability of data. It has been determined that the EMODnet information system is not merely a data repository, but also the most comprehensive open marine spatial data infrastructure on the path to a digital twin of European seas and one of the most prominent examples of cross-border marine spatial planning. A cross-sectional example for examining the ecosystem consisting of diverse spatial data types in European seas through the central portal interface is presented in Figure 5.

The *'Mid-Atlantic Ocean Data Portal'* is a user-oriented and highly interactive regional marine information system established to facilitate marine spatial planning across a vast area extending from New York to Virginia. Managed by the Mid-Atlantic Regional Council on the Ocean (MARCO), this system was developed to resolve data discrepancies and gaps between state, federal, and local agencies. It has been determined that the system incorporates a wide variety of data types, such as marine biodiversity, commercial fishing and aquaculture areas, vessel traffic routes, and particularly potential offshore wind energy sites. It has been identified that this system can transparently manage the overlapping or conflicting interests of marine and ocean users (fishermen, energy companies, environmentalists) through spatial analysis tools. A cross-sectional example for examining the spatial interaction between regional marine area use and habitat protection areas through the central portal interface is presented in Figure 6.

Based on the comprehensive analysis of six marine information systems (NOAA Marine Cadastre, AMSIS, SHOM, MDI-DE, EMODnet, and Mid-Atlantic Ocean Data Portal), the structural similarities and differences between the data classes and types hosted by these systems were identified. These systems were categorized into three groups in terms of data classes as 'comprehensive', 'restricted', and 'not available'; the comparative findings obtained are presented in Figure 7.

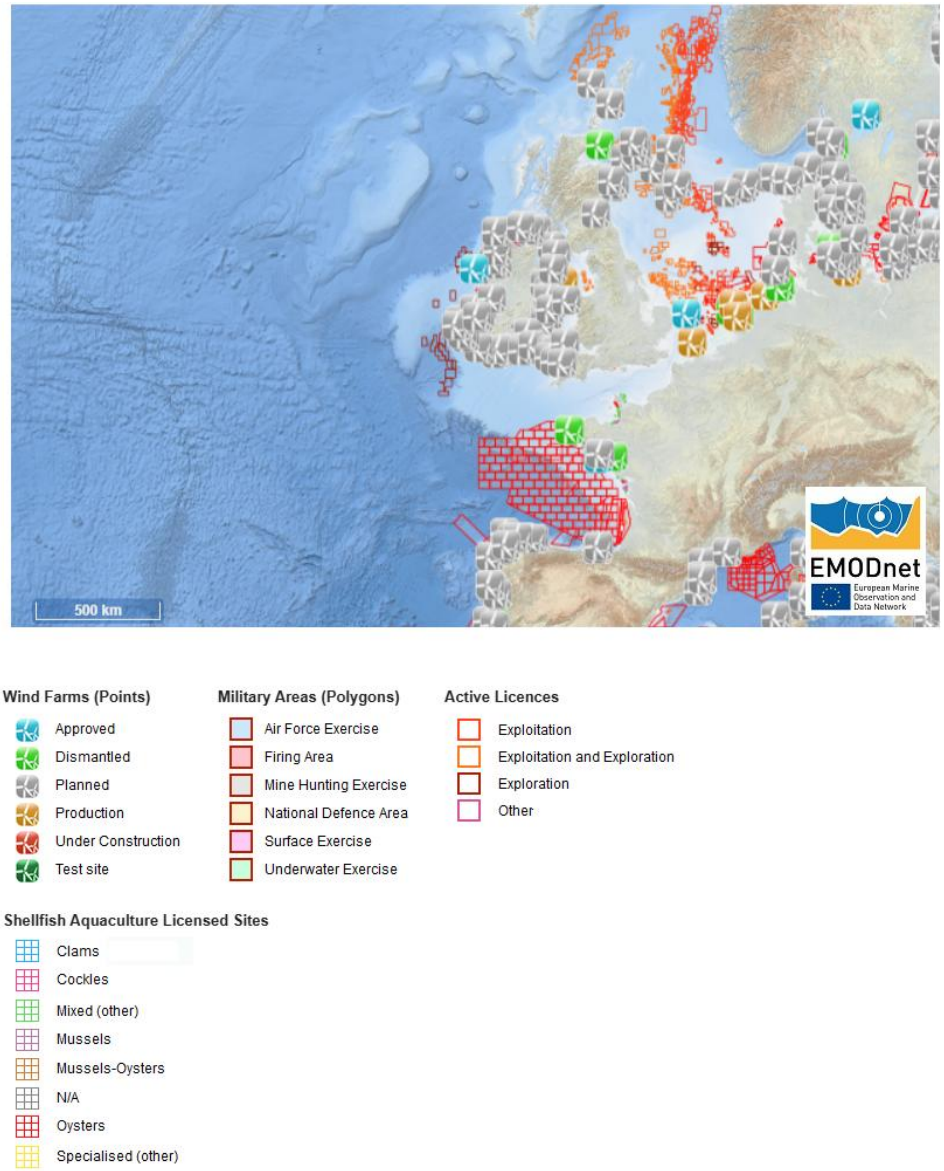

Figure 5. The EMODnet information system interface and data types

According to the results of the analysis, the results show that the EMODnet and Mid-Atlantic Ocean Data Portal systems possess the most comprehensive diversity of data types in 7 out of the 10 data classes examined. This can be explained by the fact that this situation stems from the fact that these systems are designed on a regional scale that transcends national boundaries (such as the European Union and Mid-Atlantic marine areas) and are structured through a multi-party inter-institutional cooperation model. In contrast, it has been determined that the SHOM marine information system regarding French marine areas has a narrower scope compared to other examples and predominantly focuses on hydrographic and oceanographic data sets. This highlights the direct impact of the systems' establishment purposes and target user groups on the data architecture.

It has been observed that identical or similar data contents are defined with different terminologies across various systems. For instance, it has been identified that maritime jurisdiction areas, which constitute the basis for a marine information system, are referred to as 'boundaries' in some information systems, while in others they are termed 'maritime boundaries' or 'administrative units'. This creates a need for international-level semantic interoperability and terminology.

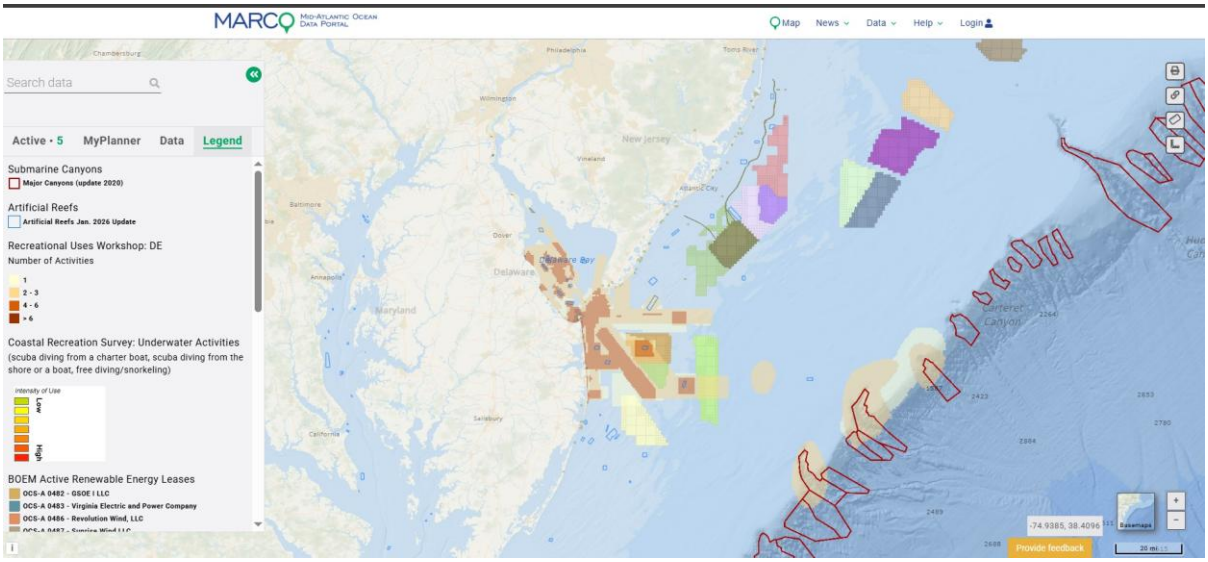

Figure 6. The Mid-Atlantic Ocean Data Portal information system interface and data types

It has been observed that European-scale systems such as EMODnet offer a data structure compliant with INSPIRE directives, whereas US-based systems like NOAA or the Mid-Atlantic portal prioritize their own national data standards (such as FGDC). This represents a key technical barrier to global-scale data integration. Comprehensive systems (e.g., EMODnet and Mid-Atlantic) are more advanced not only in terms of data diversity but also in terms of the variety of services offered for data access (WMS, WFS, API). It has been specifically observed that 'open data' policies are directly proportional to the scope of success of the system.

Data Classes	NOAA	AMSIS	MDI-DE	SHOM	EMODnet	Mid-Atlantic
Boundaries	●	●	◑	●	◑	●
Marine Activities	●	●	●	◑	●	●
Infrastructure	●	●	●	◑	●	●
Marine Transportation	●	◑	◑	◑	●	●
Marine Habitats	●	●	●	○	●	●
Oceanography	◑	◑	●	●	●	◑
Nature, Environment	◑	◑	●	◑	●	●
Base Map / Plan	○	◑	○	○	○	●
Geology	◑	◑	●	◑	●	○
Recreation	○	○	○	○	○	●

● Comprehensive ◑ Restricted ○ Not Available

Figure 7. A comparative analysis of marine information systems based on data classes

Identification of Data Classes and Types for the Turkish Marine Information System

This section is based on the synthesis of findings from the previous analyses with Türkiye's unique legal, technical, and administrative conditions. As a result of this evaluation, 88 fundamental marine spatial data types have been identified to be integrated into the system in the initial phase, forming the core structure of the developed Turkish Marine Information System (Figure 8). These data were grouped based on by considering the classification methods used in the information systems of developed countries and international organizations, alongside Türkiye's current conditions and requirements; thus, the fundamental data classes for the Turkish

Marine Information System have been established. Detailed explanations regarding these identified data classes and the marine spatial data types contained within them are presented below in a systematic manner.

The *'Marine Spatial Planning Base Data'* data class includes planning bases and fundamental reference datasets to be produced within the scope of the planned use and management of marine areas. Within this class, in addition to planning data such as marine spatial plans and integrated coastal zone plans, technical bases such as nautical charts, satellite imagery, aerial photographs, and orthophoto maps are included. This data class has been established to serve as the primary spatial reference framework for decision-support mechanisms in marine areas.

The *'Marine Cadastre'* data class is designed to encompass spatial and metadata to be produced within the scope of marine cadastre. This class includes coastal parcel polygon data, marine parcel polygon data, coastal parcel line data, marine parcel line data, and marine cadastral maps, as well as metadata specifying the rights, responsibilities, and restrictions (RRR) associated with these parcels (Figure 8).

Türkiye Marine Information System				
Marine Spatial Planning Base Data	**Marine Cadastre**	**Marine and Coastal Boundaries**	**Marine Use**	**Coastal Use**
Marine Spatial Planning	Coastal Parcel Polygon Data	Internal Waters Boundary	Weir and Fishery Areas	Coastal Erosion and Accumulation Data
Integrated Coastal Zone Planning	Marine Parcel Polygon Data	Coastal Waters Boundary	Military Training and Firing Zones	Reclamation Areas
Nautical Charts	Coastal Parcel Line Data	Territorial Waters Boundary	Military Forbidden Zones	Coastal Energy Facilities
Aerial Photographs and Orthophoto	Marine Parcel Line Data	Contiguous Zone Boundary	Shipwreck and Minefields	Fishing Ports
Satellite İmagery	Marine Cadastral Maps	Continental Shelf Boundary	Submarine Pipelines	Shipyards
		Exclusive Economic Zone Boundary	Submarine Cable Lines	Fish Markets
		Marine Administrative Boundary	Mineral and Oil Exploration-Operation Sites	Coastal Structures and Facilities
		Port Administrative Boundary	Dredging and Sand-Gravel Extraction Areas	Seawater Desalination
		Shoreline	Aquaculture Sites	Land Use and Land Cover
		Shore Edge Line	Fishing Sites	Coastal Settlement Population Data
		First 50-meter Shoreline	Offshore Renewable Energy Sites	River Flood Impact Areas
		Second 50-meter Shoreline	Marine Airport Areas	Lighthouses
		Coastal Guard Areas	Port Areas	
		Mania Line	Anchorage	
		River Boundary	Marine Highways	
			Deep-Sea Discharge Sites	
			Scientific Research Areas	
			Buoy and Warning Light	
Oceanography	**Marine Transport**	**Nature and Environmental Protection**	**Marine Habitats**	**Tourism and Recreation**
Bathymetry	Real-Time Marine Traffic Monitoring Data	Protected Areas	Marine Habitat Area	Tourist Activity and Sporting Areas
Bathymetry Contours	Spatial Marine Traffic Density	Artificial Reefs and Underwater Structures	Coastal Habitat Area	Diving-Restricted Zones
Seafloor Altimetry	Straits and Canals	Hazardous and Restricted Zones		Tourism Facilities
Marine Geology				
Submarine Fault Lines				
Marine Seismic Data				
Tidal Data				
Hurricane Data				
Marine Volcanism Data				
Seabed Landslide Data				
Tsunami Data				
Marine Mineral Data				
Marine Hydrocarbons and Hydrates Data				
Marine Water Quality Parameters				
Marine Pollution Data				
Swimming Water Quality Data				
Marine Meteorological Data				
Marine Noise Level Data				
Sea Level and Anomalies				
Seawater Salinity Data and Anomalies				
Seawater Temperature Data and Anomalies				
Seawater Chlorophyll Data				

Figure 8. A comparative analysis of marine information systems based on data classes

The 'Marine and Coastal Boundaries' data class covers the maritime jurisdiction areas and administrative boundary data of Türkiye within the framework of international law and national legal regulations. Within this scope, the following spatial data types related to maritime jurisdiction boundaries have been identified: internal waters boundary, coastal waters boundary, territorial waters boundary, contiguous zone boundary, continental shelf boundary, and exclusive economic zone (EEZ) boundary. Furthermore, the class includes multi-administrative and managerial boundaries such as marine administrative boundaries, port administrative area boundaries, coastline, shore edge line, first 50-meter shoreline, second 50-meter shoreline, coast guard areas of responsibility, obstacle limitation surfaces (mania line), and river boundaries.

The *'Marine Use'* data class is designed to encompass spatial data related to usage activities occurring in marine areas. Within this class, the following spatial data types have been defined: weir and fishery areas (dalyan and voli), military training and firing zones, military forbidden zones, shipwreck and minefields, submarine pipelines, submarine cable lines, mineral and oil exploration-operation sites, dredging and sand-gravel extraction areas, aquaculture sites, fishing sites, offshore renewable energy sites, marine airport areas, port areas, anchorage areas, marine highways, deep-sea discharge sites, scientific research areas, and buoy and warning light locations (Figure 8).

The *'Coastal Use'* data class is designed to encompass spatial data related to usage activities occurring in coastal areas, as well as natural and artificial features in these zones. Within this class, the following spatial data types have been defined: fishing ports, shipyards, fish markets, reclamation areas, seawater desalination plants, land use and land cover, coastal settlement population data, river flood impact areas, lighthouses, coastal energy facilities, and coastal erosion and accumulation data.

The *'Oceanography'* data class is designed to encompass data related to the physical, chemical, biological, and geological characteristics of the seas. Within this class, the following spatial data types have been defined: bathymetry, bathymetric contours, seafloor altimetry, marine geology, submarine fault lines, marine seismic data, tidal data, hurricane data, marine volcanism data, tsunami data, marine mineral data, marine pollution data, seawater chlorophyll data, seawater temperature, and seawater salinity, among others (Figure 8).

The *'Marine Transport'* data class is designed to encompass data related to the management of maritime transport networks and improving navigation safety. Within this scope, the following spatial data types have been defined: real-time marine traffic monitoring data, spatial marine traffic density data, and straits and canals. The *'Nature and Environmental Protection'* data class is designed to encompass on ecological and biologically sensitive areas for the sustainable use of marine areas. These include hazardous and restricted zones, protected areas, artificial reefs, and underwater structures. The *'Marine Habitats'* data class is designed to define the distribution and characteristics of different habitat types within the marine ecosystem. This class facilitates the monitoring of ecosystem health by consolidating ecological characterization of habitats and biodiversity inventories into a structure compliant with international standards. Marine habitat area and coastal habitat area data are grouped under this class.

The *'Tourism and Recreation'* data class is designed to encompass data related to the use of coastal and marine areas for tourism purposes. This class is structured to model the spatial distribution of tourist activities, usage intensity, and recreational potential. Within this class, spatial data types related to tourist activity and sporting areas, diving-restricted zones, and tourism facilities have been defined (Figure 8). On the other hand, it is recommended that the system be designed with a flexible structure and the integration of new data types into the system whenever necessary.

Identification of the Responsible Institution for the Turkish Marine Information System

It has been determined that various institutions and organizations in Türkiye possess diverse duties, authorities, and responsibilities regarding the production, updating, security, sharing, and determination of usage standards for spatial and attribute data concerning coastal and marine areas. Issues such as the redundant production of spatial data by different institutions in varying standards, leading to losses in efficiency, time, and resources, remain a key issue in geographic information systems. Therefore, countries strive to establish and strengthen national geographic data infrastructures to produce accurate policies, strategies, and decisions, and to ensure interoperability as well as effective resource and technology management. To operate such spatial and verbal data for coastal and marine areas—produced or used by different institutions—through a single platform and to ensure the necessary coordination and cooperation between spatial data producers and users, the establishment of a marine and coastal information system is required. Identifying the institution responsible for managing such a system is one of the most critical steps in this process.

Declarations published by international organizations, such as the United Nations Integrated Geospatial Information Framework (UN-IGIF), emphasize the necessity of having a dedicated unit responsible for coastal and MSDI. In this context, an examination of systems in countries that have established or are developing marine information systems shows that institutions such as the Federal Department of Fisheries and Oceans (DFO) in Canada, the National Oceanic and Atmospheric Administration (NOAA) in the United States, the Department for Environment, Food and Rural Affairs (DEFRA) in the United Kingdom, the Geodata Agency in Denmark, Geoscience Australia in Australia, and the Ministry of Mining, Blue Economy and Maritime Affairs

in Kenya are identified as the authorities responsible for marine information systems. In Türkiye, some of the establishment, duties, and responsibilities of the General Directorate of Geo-Information System have been regulated in the Presidential Decree No. 1 on the Presidential Organization, dated 2018, as follows:

- To carry out the tasks and procedures related to the establishment, use, and development of the National Geographic Information System,
- To conduct studies and prepare the necessary legislation to ensure the determination of standards, as well as the fundamental policies and strategies regarding the national-level production, quality, and sharing of spatial data and information,
- To establish and operate the portal where spatial data produced by public and private sector institutions and organizations are presented.

Pursuant to Article 3 of Presidential Decree No. 49 on Geographic Information Systems, dated 2019, it has been identified that the General Directorate of Geo-Information System is held responsible for carrying out procedures related to the national geographic information system and infrastructure. Furthermore, one of the primary objectives in the 2024–2030 National Geographic Information Strategy and Action Plan of the General Directorate of Geo-Information System has been identified as strengthening the Directorate's guiding and regulatory role in the sector and establishing and disseminating standards by integrating contemporary technologies with geographic information systems.

In Presidential Decree No. 4 on the Organization of Affiliated, Related, and Associated Institutions and Organizations and Other Institutions and Organizations, dated 2018, some of the 'establishment, duties and responsibilities of the Office of Navigation, Hydrography, and Oceanography (SHOD)' have been regulated as follows:

- To carry out navigation, hydrography, and oceanography services and duties within the borders of national sovereignty, under the Turkish Naval Forces Command,
- To archive all kinds of data, plans, and maps belonging to hydrographic, oceanographic, and geophysical surveys and research to be conducted by public and private institutions and individuals through special means.

Pursuant to Article 14 of the Regulation on Navigation, Hydrography, and Oceanography Services (No. 30941), dated 2019, it has been identified that SHOD is held responsible for *'conducting all types of hydrography, oceanography, marine geophysics, and geology surveys, research, and works for military, scientific, and economic purposes within our maritime jurisdiction and interest areas under a specific plan and program,'* and for *'carrying out the duties of the national hydrography, oceanography, marine geology, and geophysics data and information center and archive.'*

A holistic evaluation of current legislation indicates that, in accordance with Presidential Decree No. 4 on the Organization of Affiliated, Related, and Associated Institutions and Organizations and Other Institutions and Organizations, duties for military and strategic purposes regarding marine areas have been entrusted to SHOD. In contrast, within the scope of the Presidential Decree No. 1 on the Presidential Organization, the General Directorate of Geo-Information Systems has been assigned tasks such as the collection and processing of spatial data in marine areas and associating them with data from different institutions.

Since marine areas are the intersection points of a wide variety of activities (transportation, tourism, fishing, energy, etc.), the information system to be developed in these areas must provide an infrastructure that not only stores data but also strengthens decision-support mechanisms, guides planning processes, and facilitates inter-institutional cooperation. Therefore, the institution to be responsible for the management and coordination of the system in question should:

- Possess a modern and technical infrastructure,
- Be experienced in data management and spatial information systems,
- Have legal and administrative competence to ensure inter-institutional coordination.

When evaluated within this framework, the General Directorate of Geo-Information Systems, which is currently responsible for the coordination of TUCBS, emerges as the most suitable institution to lead the marine information system. Given its technical capacity and experience in determining and managing national standards for geographic information systems, this institution is structured to collect and analyze data from various

institutions and sectors under a common umbrella, thereby providing reliable outputs for decision-making processes.

Conclusion

In this study, internationally recognized marine information systems were analyzed in detail, and 10 fundamental data classes and 88 data types that should be included in the initial phase of the Turkish Marine Information System were identified as essential for the initial phase. A strategic analysis was conducted to identify the institutional structure responsible for this system, taking Turkey's unique conditions into account. Within this scope, it has been evaluated that The General Directorate of Geo-Information System possesses the institutional capacity, knowledge, and experience required to implement and ensure the sustainability of the marine information system application.

The design and implementation of a marine information system enable users, practitioners, and managers with the opportunity to describe, analyze, and present spatial information in detail regarding different marine layers, such as the sea surface, water column, seabed, and subsoil (Uslu & Sesli, 2011). This comprehensive system enables a holistic approach to economic, socio-cultural, physical, and biological structures, as well as the rights, responsibilities, and restrictions (RRR) associated with public and private entities in marine areas. Such a system not only supports technical and administrative decision-making processes but also contributes to efforts aligned with the United Nations Sustainable Development Goals (Hafizh & Djunarsjah, 2024). Furthermore, it holds great importance in providing accessible, reliable, and up-to-date spatial data for policymakers, planners, technical staff, the private sector, coastal and marine authorities, academia, and the public.

The fundamental vision of the Turkish Marine Information System should be:

- To increase the understanding and use of spatial information related to marine areas,
- To enhance access, usability, integration, and sharing of spatial information concerning marine areas,
- To promote the efficient, effective, and economical use of digital marine spatial information and to enable its interoperability with relevant hardware and software systems,
- To contribute to sustainable development at local, regional, and global levels and to encourage the establishment of spatial data infrastructures.

The implementation of a marine information system in Türkiye will enable, 'integrated coastal zone management', 'marine spatial planning', and 'marine cadastre' efforts will have access to reliable, up-to-date, and accurate spatial data at international standards. This system will contribute to the decision-making, implementation, monitoring, and management processes of the relevant studies. Furthermore, by providing marine spatial data through an information system, it will enable answering key spatial questions such as “what,” “where,” “how much,” and “how” regarding usage activities, thereby maximizing the value of marine spatial data. Consequently, more effective use and management of coastal and marine areas will be ensured, contributing to the protection of the ecosystem and forming a significant step toward achieving sustainable development goals.

Recommendations

Efforts should be initiated to establish a marine spatial data infrastructure in Türkiye that is compliant with international standards and interoperable with global systems. Following its establishment, 'marine information system' and 'marine cadastre' studies should be developed concurrently and implemented as a priority. Furthermore, further studies should focus on integrating the marine information system with TUCBS. This will represent a significant step toward achieving sustainable land management goals and ensuring the integrity of the national spatial data infrastructure. Additionally, a new umbrella organization (such as a Ministry of Maritime Affairs) responsible for these processes should be established to strengthen the technical infrastructure in the management of coastal and marine areas, institutionalize inter-institutional cooperation, and implement holistic policies.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPHELS journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest.

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