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IS INSPIRE ABLE TO SUPPORT MARINE STRATEGY FRAMEWORK DIRECTIVE's (MSFD) DATA REQUIREMENTS?

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IS INSPIRE ABLE TO SUPPORT MARINE STRATEGY FRAMEWORK DIRECTIVE's (MSFD) DATA REQUIREMENTS?

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None of all this would have happened, though, without my family. My parents who offered me the opportunity to continue studying and broaden my horizons. With their love, encouragement and emotional support they assisted me in all the difficult times

but also supported my will to continue working hard for achieving the best possible result. Also, I want to say a big thank you to my most dedicated partner in and outside the university life, Georgios, who was there to listen, assist, encourage, support me and reminded me that the process is that matters every time I thought of quitting.

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Αφιερωμένο στους γονείς μου…

Abstract

In the era of technological revolution, growth and development, information is the key sector for a country's economy and social development, evolution and prosperity. An important factor for development is the use of geoinformation technology that enables management, processing and distribution of spatial data. In Europe the SDI implementation is stimulated by the INSPIRE (Infrastructure for Spatial Information in Europe) Directive. Quite often existing European environmental directives serve as a use case or context for the development for the INSPIRE data specifications. For the marine domain, the Marine Strategy Framework Directive (MSFD) is a case-Directive that needs INSPIRE data support for assessing the quality of EU marine waters. MSFD does not enquire the collection of new information and should focus on specific aspects that are listed in Annex III of the INSPIRE Directive. The INSPIRE Directive and the MSFD Directive are implemented in a parallel both making use of existing information for serving their scopes. This research gives answers to whether INSPIRE can support the MSFD's data requirements, if there is semantic interoperability between INSPIRE on attributes level and the MSFD data requirements and if the available INSPIRE data are findable, accessible, interoperable and reusable.

INSPIRE Data Specifications were studied for finding marine-related concepts in their scopes. It was proved that 20 INSPIRE Data Specifications were able to serve the MSFD data requirements. The assessment of semantic interoperability between the two Directives was a challenging process. The MSFD requirements were used as keywords for exploring through the UML data models of INSPIRE and search marine-related spatial objects and attributes. The research revealed that there was high naming heterogeneity between the two Directives. Thus, in most of the cases there was no semantic interoperability between the INSPIRE data and the requirements of MSFD.

In the last phase of this research, the FAIR Data Principles were used for evaluating the INSPIRE data. INSPIRE was assessed conceptually and found to be in line with the FAIR principles in a high degree. However, when assessing the data per se the situation differentiated. INSPIRE Geoportal was used for searching the metadata records that are available under five categories: datasets, series, layers, services and download service spatial data sets. The search was limited to three case countries participating in the INSPIRE Marine Pilot Project (IMPP): the Netherlands, Germany

and Denmark. The assessment resulted that the INSPIRE metadata are Findable and Accessible in a lesser degree than they are Interoperable and Accessible.

Finally, some recommendations are proposed. Since there was created an ad-hoc "Glossary for MSFD Terms", it is suggested that this glossary will be reviewed and enriched for future assessments like the semantic interoperability of INSPIRE and MSFD. The INSPIRE Geoportal should improve the cross-language query by adding more synonyms. Thus, more results will be received in the searching process. The INSPIRE website, should be enriched with case studies like the IMPP and with information about difficulties in the process. Last of all, it is proposed that INSPIRE could adopt the FAIR data principles as a tool for improving its existing (meta)data, while also using them for producing data of better quality in the future.

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Chapter 1. Introduction

In the era of technological revolution, growth and development, information is the key sector for a country's economy and social development, evolution and prosperity. An important factor for development is the use of geoinformation technology that enables management, processing and distribution of spatial data. Countries around the world, organize their spatial data by implementing Spatial Data Infrastructures (SDI).

An SDI is defined as "[…] the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of - and access to - spatial data. The SDI provides a basis for spatial data discovery, evaluation, and application for users and providers within all levels of government, the commercial sector, the non-profit sector, academia, and by citizens in general" (GSDI Association, 2004). SDI is considered as a long- term evolving process, without a priori known results (Tziachris et al., 2013).

INSPIRE Directive

In Europe the SDI implementation is stimulated by the INSPIRE (Infrastructure for Spatial Information in Europe) Directive[1].This directive aims at facilitating the exchange and sharing of spatial data among the Member States (MS). The INSPIRE Directive came into force in May 2007 and is implemented in stages with full implementation by 2021 (INSPIRE> Implement).

The concept behind the implementation of INSPIRE Directive (2007/2/EC), is the creation of a pan-European SDI for the environment. The main driving force is the need for environmental management and impact assessment cross national borders of the European MS. For example, air pollution, flooding and protection of endangered species), require the creation and sharing of spatial data across Europe. Thus, the INSPIRE directive was introduced with a focus on *data specifications*, *data harmonization* and *interoperability* of spatial data is support of many environmental European (EU) Directives.

[1] As it is stated Article 3 of the INSPIRE Directive *"infrastructure for spatial information"* means metadata, spatial data sets, and spatial data services; network services and technologies; agreements on sharing, access and use; and coordination and monitoring mechanism, processes and procedures, established, operated or made available in accordance with this Directive

INSPIRE Use cases

For the development of the data specifications, environmental use cases and application scenarios were used. An environmental use case is defined as: "*A use case is initiated by a user with a particular goal in mind and completes successfully when that goal is satisfied. It describes the sequence of interactions between actors and the system necessary to deliver the service that satisfies the goal*" (D2.6_v3.0, p.36).

Quite often existing European environmental directive serve as a use case or context for the development for the INSPIRE data specifications. In the domain of "hydrography" this is e.g. the case with the Water Framework Directive(2000/60/EC), the Flood risk management Directive (COM (2004)472) and the Bathing Waters Directive (2006/7)

For the marine domain, the Marine Strategy Framework Directive (MSFD) is a case-Directive that needs INSPIRE data support for assessing the quality of EU marine waters and proceed to monitoring activities for ensuring the marine water quality.

Marine Strategy Framework Directive (MSFD)

The Marine Strategy Framework Directive (MSFD) has as an overall goal to achieve or maintain the Good Environmental Status [2](GES) in the marine environment by 2020 (SEC (2011)1255 final). Article 11 of the MSFD provides legally-binding requirements for the Member States to establish and implement coordinated monitoring programs for the ongoing assessment of the environmental status of marine waters. (European Commission. 2014)

MSFD is the first legal act that requires the integration of ecological and socio-economic data as well as the integration of policies. MSFD does not enquire the collection of new information and should focus on specific aspects that are listed in Annex III of the Directive. These aspects should be considered when doing an initial assessment MSFD is considered as a landmark in the effort of integrating all these different aspects for assessing the status of the marine waters. (Bigagli E., (2016 March 18) Skype interview). What MSFD requires, is spatial data that can be grouped in two sets (Figure 1):

[2] Good Environmental Status (GES) means the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations (OJ L 164, 25.6.2008, p.25)

- 1st set: The data needed for the initial assessment of EU marine water
- 2nd set: The data needed for monitoring the marine environment as they are listed in in Annex III of the MSFD plus all the ones listed in Annex V. (Bigagli E., (2016 March 18) Skype interview).

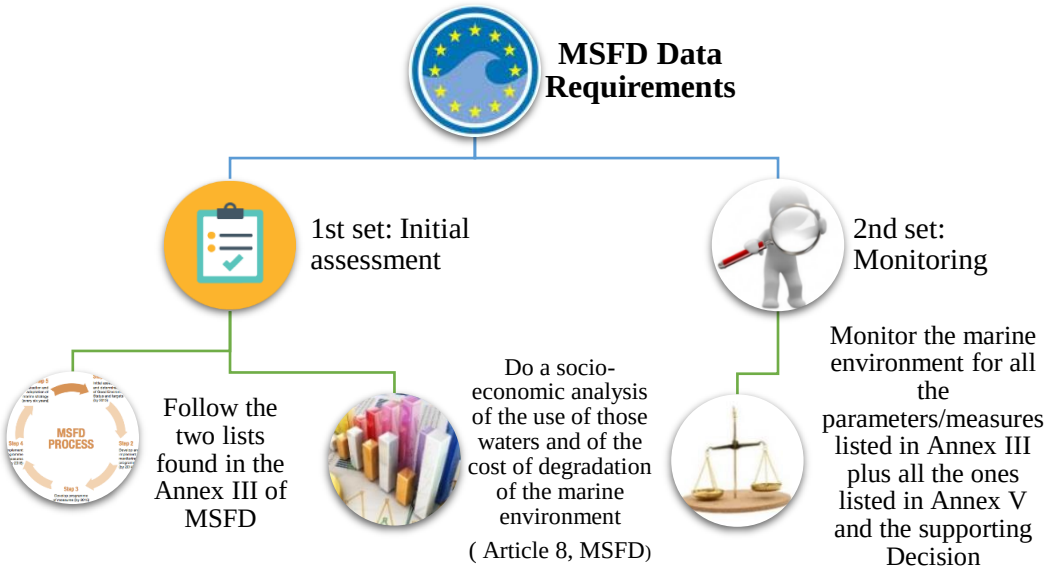

Figure 1: Marine Strategy Framework Directive (MSFD) Data Requirements

INSPIRE and MSFD interaction

The INSPIRE Directive and the MSFD Directive are implemented in a parallel both making use of existing information for serving their scopes. To explore the link between INSPIRE and the MSFD, the INSPIRE Marine Pilot Project (from now on referred as IMPP) was executed. The objective of the IMPP was the support of the Member States in the implementation of both directives (INSPIRE and MSFD) (Call INSPIRE Marine Pilot, 2014). The IMPP, initially, used the data holdings of Netherlands (NL), Germany (DE) and Denmark (DK). The first phase of the IMPP project is finished. The conclusions of the IMPP project show that INSPIRE Data Themes are, theoretically, related to the requirements of MSFD. The assessment also showed that there is semantic interoperability[3] between INSPIRE and the MSFD requirements.

[3] Semantic interoperability is about making sure that "two communicating systems interpret the information the same way" (Vernadat, 2007:143); aligned legislation and legal meaning (ISA Program, 2014)

Problem statement

The MSFD, is rather complicated regarding its spatial data requirements. The IMPP was intended to answer the question to what extend a conceptual and semantic relationship between MSFD and INSPIRE exists or can be achieved. IMPP was partly successful in answering this question. IMPP had a quick scan character with as a result that a detailed methodology on how these results were produced was not clearly indicated. Furthermore, for the assessment of semantic interoperability between MSFD's data requirements and the available INSPIRE data was only done for a few INSPIRE Data Themes. Also, due to the quick scan character of the work, a detailed methodology how and why the authors came to certain conclusions was not clear.

This research builds on the results of the IMPP's first deliverable as for the conceptual linkage of INSPIRE Data Themes and MSFD's requirements and on the IMPP's second deliverable as for the existence of semantic interoperability between the two Directives. These results are extended with the creation of a methodology on how to prove the existence of this linkage between the Directives: the step by step identification of the level of semantic interoperability between INSPIRE and MSFD. This identification will be held by examining the 34 INSPIRE Data Themes and by evaluating the available data for being findable, accessible, interoperable and able to be reused in the future.

To begin with, there is a need for a conceptual[4] review on to what extend INSPIRE can support MSFD's data requirements. This review will be based on a specific methodology, by using existing literature. Moreover, INSPIRE was meant for data harmonization and interoperability. Semantic interoperability is a key factor for achieving harmonization (INSPIRE Drafting Team "Data Specifications," 2007:30). Therefore, studying the semantic interoperability between the INSPIRE data and MSFD data requirements is rather crucial. Another aspect that still needs further examination, is whether the data mentioned in the conceptual part, are indeed findable, accessible, interoperable and can be used in practice in a MSDF use case.

[4] Conceptual in this research means theoretical

Research Objective and Research Questions

Research Objective

Since MSFD mentions INSPIRE Directive as a potential data source, it forms a good case to investigate to what extent INSPIRE is ready to serve the MSFD data requirements.

Research Questions

1. Are the INSPIRE Data Themes able to support the MSFD on a conceptual level?
2. Is there semantic interoperability, on attributes level, between the INSPIRE data specifications and the MSFD data requirements?
3. Are INSPIRE data, findable, accessible, interoperable, and reusable to serve MSFD reporting?

Thesis overview

This research is organized into the following chapters:

In Chapter 1 is the background information, the problem definition, the objective and the research questions and the organization of the report are presented

In Chapter 2 is the methodology utilized for answering the three research questions is explained.

In Chapter 3, the results of the three research questions are presented

In Chapter 4 a discussion about the findings and the general overview of the results of this work is presented.

Chapter 5 comprises the conclusions of this research and some recommendations for further analysis that would be beneficial for better implementation of INSPIRE.

In the end of the thesis report, there is the reference list followed by all the Appendices created in the procedure followed by the analysis of the findings.

Chapter 2. Methodology

2.1 Overall methodology for answering the three research questions

For examining to what extend INSPIRE can serve MSFD's spatial requirements, an extensive literature research will be done, and three research questions were formulated for achieving the research objective. This first phase is the literature research on the theoretical background of the two directives, the scope they serve and the relationship that exists between them. All information is chosen from existing literature. The second phase is to try answering the three research questions: the conceptual approach on whether INSPIRE Data Themes can serve MSFD's spatial requirements (RQ1), the existence or no existence of semantic interoperability between the two Directives on attributes level (RQ2) and what is the user's experience when it comes to finding the data in practice (RQ3). In the last question, the data will be assessed by using the FAIR Data principles. A schematic representation of the methodology followed for answering the RQs is presented in Figure 2, below. Finally, the results are discussed, and conclusions are drawn as well as future recommendations and improvements that need to be done.

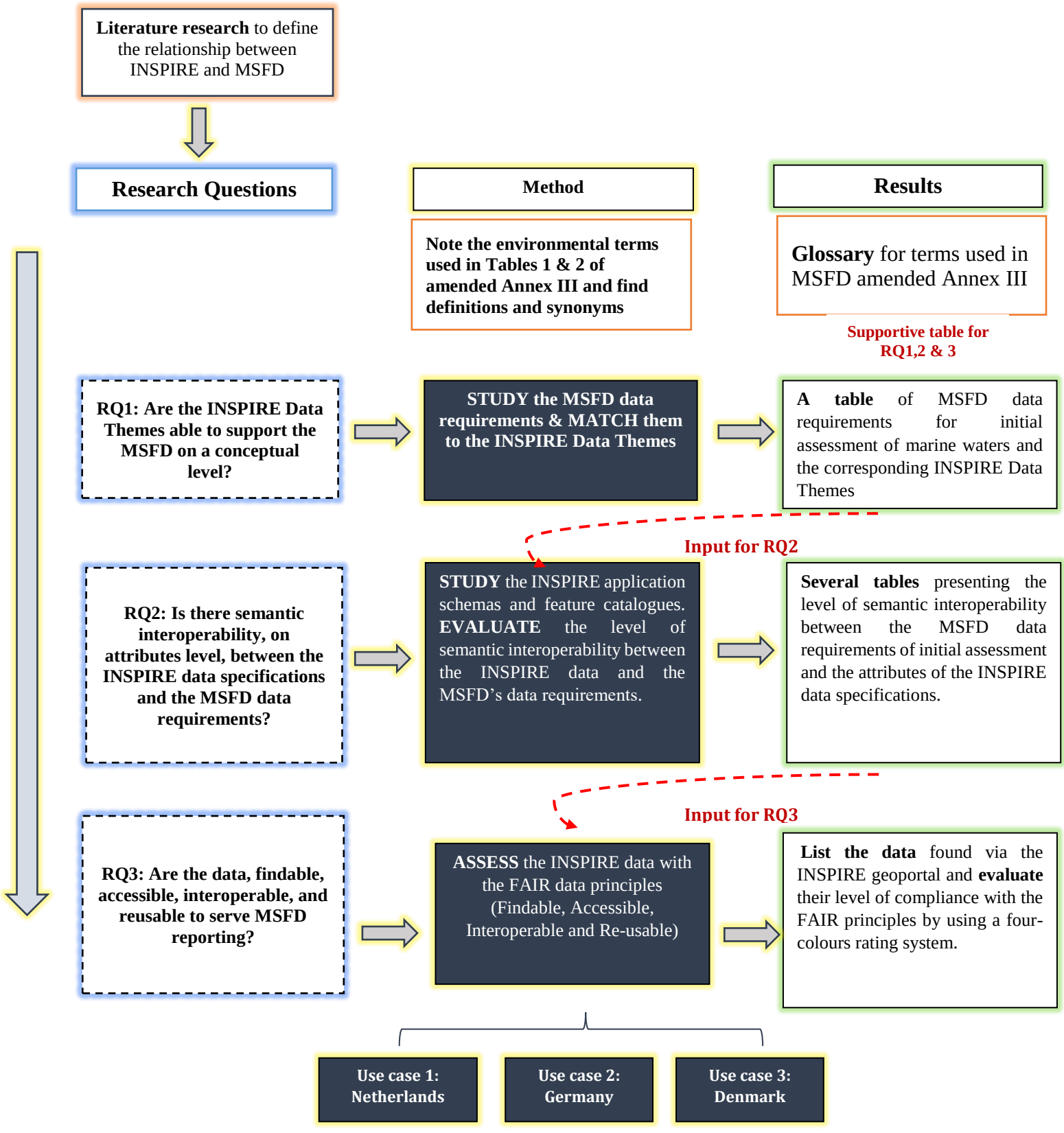

Figure 2. Overall Thesis Methodology

2.2 Creation of "Glossary for terms" used in the amended Annex III (OJ 125, 18.5.2017, p.30-33)

MSFD is an environmental directive with multiple requirements as for the initial assessment of the marine waters listed in the Tables 1 and 2 of Annex III. To answer the questions regarding the ability of INSPIRE to support the spatial requirements of such a directive, the priority is to note all these requirements one by one and define them respectively. There are many supporting documents for explaining some of the terms used in the Directive (such as the Technical report from DCE-Danish Centre of Environment and Energy No.16 "A Glossary of terms commonly used in the MSFD" or controlled vocabularies related to specific elements that are linked to other EU legislations). However, to date, there is no official Glossary of MSFD requirements where all terms are grouped and defined. Thus, for this research, this Glossary was necessary for grouping all MSFD terms, define them and find synonyms.

For defining the MSFD terms, the General Multilingual Environmental Thesaurus (GEMET) will be used. GEMET is available from the European Environment Information and Observation Network (EIONET). INSPIRE, also, uses GEMET as a controlled vocabulary. "*A controlled vocabulary is an organized arrangement of words and phrases used to index content and/or to retrieve content through browsing or searching. It typically includes preferred and variant terms and has a defined scope or describes a specific domain.*" (Harpring, 2010; p.12)

In cases where the term is not available via GEMET, the term is defined according to a common dictionary i.e. Cambridge dictionary.

Furthermore, a list of synonyms to the MSFD terms will be needed for some parts of the research. GEMET does not include any synonyms for the registered terms. Thus, for each term, synonyms are searched in common dictionaries i.e. Cambridge dictionary.

The result will be a Glossary in a tabular form, where all the MSFD terms will be listed together with their definitions and synonyms The Glossary will be available under Appendix 1.

2.3 Research Question 1: Are the INSPIRE Data Themes able to support the MSFD on a conceptual level?

In Chapter 1, it is discussed that INSPIRE Directive is the pan-European SDI for the environment. "*Datasets in scope of INSPIRE are ones which come under one or more of the 34 spatial data themes set out in the INSPIRE Directive*" (Data Specifications, 2017). INSPIRE Directive sets rules, the Implementing Rules (IRs), for what should be implemented and how. Yet, IRs specify what should be implemented in a more generic and abstract way. Thus, there are the Technical Guidelines (TGs) (also referred as the Data Specifications (DSs)), which specify how the legal obligations should be implemented while referring to existing geospatial standards when needed. These DSs "specify common data models, code lists, map layers and additional metadata on the interoperability to be used when exchanging spatial datasets" (Data Specifications, 2017)

The INSPIRE Data Themes include a variety of datasets which are related to several domains, mainly environmental. In this research, the focus is on the marine domain and MSFD is used as a case study. MSFD is an environmental Directive that requires spatial data to underpin its goals. MSFDs data requirements for the initial assessment of the marine waters are specified in Annex III of DIRECTIVE 2008/56/EC. However, in 17 May 2017, the European Commission "amended the DIRECTIVE 2008/56/EC as regards the indicative lists of elements to be taken into account for the preparation of marine strategies". (OJ L125,18.5.2017, p.28). MSFD, in the amended Annex III, sets indicative lists of ecosystem elements, anthropogenic pressures and human activities relevant to the marine waters, in two tables. Table 1 includes elements for the structure, the functions and the processes of marine ecosystems (OJ L125,18.5.2017, p.30). Table 2, includes elements for the anthropogenic pressures, uses and human activities in or affecting the marine environment.

This research has started by 2015 and is ongoing until 2017. Since the amended MSFD Annex III was published earlier this year, the methodology and the results are adjusted to this most current version.

The steps followed for answering this question are presented below:

Step 1: Study the DIRECTIVE (EU) 2017/845 5 and the DSs of the INSPIRE Data Themes

Step 2: Find the MSFD data requirements (as they are listed in Annex III Tables 1, 2a and 2b). The structure of the amended Annex III differs when compared with the older Annex III version. There is a new column titled "Theme". This column categorizes the requirements in a straightforward way e.g. for the Theme "Species" we can assume that relevant spatial information can be found under the INSPIRE Data Themes "Species Distribution" or "Habitats and Biotopes".

Step 3: The linkage between the MSFD requirements and the IDSs will be based on the scope of each IDS. Each MSFD Theme will be linked to one or more IDSs that seem, in a conceptual level, to include relevant attributes.

Expected results:

- **Appendix 2 (Table 2-1, 2-2a & 2-2b):** List of all the MSFD data requirements for initial assessment of waters, as they are listed in Annex III of the DIRECTIVE (EU) 2017/845, together with their supporting INSPIRE Data Themes.
- **A summary section** where the results for the two versions of Annex III will be briefly compared.

[5] OJ L125,18.5.2017, p.30-33

2.4 Research Question 2: Is there semantic interoperability, on attributes level, between the INSPIRE data specifications and the MSFD data requirements?

As introduced in Chapter 1, INSPIRE Directive is aiming at harmonization and interoperability of spatial data. Interoperability is a prerequisite for achieving data harmonization. Interoperability, within the context of INSPIRE, means "*the possibility for spatial data to be combined, and for services to interact, without repetitive manual intervention, in such a way that the result is coherent, and the added value of the data sets and services is enhanced"* (INSPIRE Directive).

There are four types of interoperability as reported by Rezaei et al. (2014) and (ISA Program, 2014): the syntactic, the semantic, the technical and the organizational interoperability.

- Syntactic interoperability (or Legal interoperability as referred by ISA Program) is *"defined as the ability to exchange data and is associated with data formats"* (Rezaei et al., 2014).
- Semantic interoperability is about making sure that "two communicating systems interpret the information the same way" (Vernadat, 2007:143); aligned legislation and legal meaning (ISA Program, 2014)
- Technical interoperability *"is achieved among communications-electronics systems or items of communications-electronic equipment when services or information could be exchanged directly and satisfactorily between them and their users"* (Rezaei et al., 2014); Technical linking of systems (ISA Program, 2014)
- Organizational interoperability *"concerns the definition of authority and responsibility with the intention that interoperability could happen under good conditions"* (Rezaei et al., 2014)

This research focuses on one out of the four types of interoperability, the semantic interoperability. Semantics is the study of meaning. Proper understanding of the meaning allows a message to be communicated in such a way that misinterpretations

are avoided. In case of data sharing, semantic heterogeneity[6] can cause various problems which affect data interoperability. As Bishr (1998) notes, semantic heterogeneity can be either cognitive or naming. In the cognitive heterogeneity, "there is no common base of definitions of the underlying facts between the two disciplines". In the naming heterogeneity, semantically alike entities that refer to the same real-world fact are named differently. For example, "*watercourse and river might be two names describing the same thing"*. Due to the time frame, we will detect the one type of semantic heterogeneity, the naming heterogeneity, between the INSPIRE data attributes and the MSFD data requirements. Finally, we will evaluate the semantic interoperability of the data, based on the level of their semantic heterogeneity. As evidenced, high semantic heterogeneity can cause data sharing issues. Thus, the more heterogeneous the data appear to be, the less semantic interoperable they will be.

Important INSPIRE concepts

All information needed for detect the level of semantic heterogeneity between the two Directives will be derived from the DSs documents of INSPIRE. Thus, at this point it is important to introduce some general INSPIRE concepts on which the research is based on.

The INSPIRE Generic Conceptual Model (GCM)

The INSPIRE Data Specifications, for the spatial Data Themes listed in the Annexes of the INSPIRE Directive, were designed "*based on a framework that identified the components relevant to the interoperability and harmonisation of data*" (D2.7_v3.0, p.13). These components result in the so-called Generic Conceptual Model (GCM) (D2.5_v3.4rc3). Specific requirements and recommendations are within the GCM scope regarding aspects such as:

- INSPIRE application schemas
- spatial and temporal representations of spatial objects across different levels of detail
- spatial and temporal relationships between spatial objects - unique object identifiers
- constraints

[6] Heterogeneity: the case when something is consisting of parts or things that are very different from each other (Cambridge dictionary)

- reference to common spatial and temporal reference systems
- controlled vocabularies
- support for multilingual aspects (D2.5_v3.4rc3, p.5)

The INSPIRE application schemas

The DSs are formed by the international accepted standards, such as the reference model described in ISO 19101. The data required by each Data Theme, can be found in the corresponding Data Specification document under conceptual schemas, the application schemas. An application schema, according to ISO 19101, is defined as "*the Conceptual schema for data required by one or more applications*". INSPIRE application schemas are based on the GCM and maintained in the Consolidated INSPIRE Unified Modelling Language (UML) model, that also includes external schemas.

INSPIRE General Feature Model

The General Feature Model, specified by ISO 19109 Clause 7, is adopted by INSPIRE for specifying and describing the spatial objects types and their properties. It defines the concept of spatial object type and several types of properties such as attributes, association roles and so forth. (D2.5_v3.4rc3, p.37). In ISO 19101, two types of representation for spatial object types are distinguished: the application schema and the feature catalogue. These two types are both used by INSPIRE DSs, but for different purposes. (D2.5_v3.4rc3, p.37).

- The application schemas are expressed using a conceptual schema language and the associated requirements based on ISO/TS 19103. (D2.5_v3.4rc3, p.37). The language used to represent the conceptual schema of spatial data in INSPIRE is the UML.
- The feature catalogue contains a large subset of the application schema information. It is presented in a text format that is human readable. Moreover, the feature catalogues are translated in all official languages of the European Union. Also, "*the feature catalogues are published via a registry service, which allows queries on and access to the individual elements in the application schema. For instance, a human user can have access, via a portal, to the name and the definition of an entry in an enumerated value in all supported languages*". (D2.5_v3.4rc3, p. 39)

This research question aims to detect the semantic heterogeneity between the attributes of INSPIRE data and the MSFD data requirements. All relevant information about

INSPIRE data attributes will be derived by studying the application schemas and the feature catalogues of the DSs. For the MSFD, the legislation documents "OJ L164, 25.6.2008" and will be studied, thoroughly, for finding the data requirements on the initial assessment of the marine waters. The steps followed for answering this question are listed below:

Precondition: The amended MSFD Annex III shall be used. Thus, the Appendices 2a and 2b of RQ1 will be used as input for this RQ.

Step 1: Use the terms of RQ1 as keywords and search in the IDSs which, (as discussed in RQ1, see Appendix 2), are expected to include marine- related attributes in the available spatial objects. It is important to note here that in cases where any terms failed to match with the IDSs from RQ1, they will still be assessed for their semantic interoperability. The difference in their assessment lies in the fact that they will be searched in all the 34 IDSs without being tied at any.

is that these specific terms will be searched in all the 34 IDSs.

Step 2: Three cases may occur based on the search results. Here, the semantic heterogeneity will be detected.

Case 1: ***Direct Name interoperability on attributes level – No semantic heterogeneity***

If the MSFD data requirement appears with the same name in the spatial object's attributes, there is no semantic heterogeneity and there is direct name interoperability. The same situation occurs when the data requirement appears with the same name in the spatial object's name. In this case, it means that the data set includes information about this MSFD data requirement.

Case 2: ***Indirect name interoperability on attributes level – Medium semantic heterogeneity***

Subcase 2a: If the name of the MSFD data requirement is appeared in the definition of the attribute, there is medium heterogeneity. The user must search deeper to find the connection of the required data to the INSPIRE spatial object. Thus, even though the name of the requirement is defined, there is medium semantic heterogeneity in the result.

Subcase 2b: In this subcase, the name is not appeared in any of the attributes or definitions. However, relevant attributes or attribute definitions appear by using synonym words. This can be characterized indirect name interoperability and there is medium heterogeneity detected.

Case 3: ***No name interoperability on attributes level – High Semantic heterogeneity***

There is no result neither by using the name of the data requirement nor by using synonyms.

An example of the resulting table where the semantic heterogeneity will be presented follows:

MSFD data requirement name	**MSFD Keyword used for search in INSPIRE Data Theme**	**INSPIRE Data Theme**	**INSPIRE Spatial object**	**Attribute name**	**Found in**	**Level of Semantic Heterogeneity**
Spatial and temporal variation in: **bathymetry**	Bathymetry	Elevation	ElevationVectorObject	propertyType	definition	**medium**

Step 3: Based on the level of semantic heterogeneity, resulted in Step 2, the semantic interoperability between the MSFD term and the IDSs will be assessed.

Case 1: -**no semantic interoperability** for cases where the results showed **high semantic heterogeneity**

Case 2: -**moderate semantic interoperability** for cases where the results showed **medium semantic heterogeneity**

Case 3: -**high semantic interoperability** for cases where the results showed **no semantic heterogeneity**

The detailed presentation of the results can be found under Appendix 3 (Tables 1, 2a & 2b)

Analysis of the results

Terms from the Glossary have been selected in the previous steps for investigating the levels of semantic interoperability. For the analysis of the results, some cases are presented below with a specific methodology for interpreting the outcomes.

Case 1: The same term appears in multiple MSFD Themes.

Each term can be used multiple times and can appear in more than one MSDF Themes. However, for the accuracy of the results each term is considered as a unique term in the search process. For example, the term "species distribution" may appear in both "Species" and "Habitats" MSFD theme.

Case 2: The same term appears in multiple INSPIRE Themes.

In case we search in two or more INSPIRE IDSs for relevant attributes, each search is unique. Thus, the term will be counted by the times of its appearance in the search.

Case 3: One term- multiple attributes

Another case may be that for a specific term, multiple attributes may result. Since the attributes are listed in the same spatial object then the term is counted once, and the result is the mean of all results.

Example: We find a spatial object with three different attributes related to the "species distribution" term. They all result in high semantic interoperability. When analysing this result, we count 1 appearance of the term consider the one "high semantic interoperability" in the analysis.

For cases where the attributes belong to different spatial objects, please refer to "Case 2".

2.5 Research Question 3: Are the data, findable, accessible, interoperable, and reusable to serve MSFD reporting?

The data required by MSFD for the initial assessment of the marine waters are made available through the INSPIRE Geoportal. Thus, it is important to assess INSPIRE's FAIRness for drawing conclusions on their ability to serve the MSFD Reporting.

The assessment on how FAIR is INSPIRE is a two-phases approach; a theoretical assessment of the INSPIRE's FAIRness and a practical assessment of the INSPIRE's Geoportal FAIRness. For evaluating the available data we will use the FAIR Data Principles. The 15 principles - corresponde to the four letters of FAIR: Findable, Accessible, Interpoerable and Reusable – are related, but indipendent and separable (Wilkinson et al., 2016; p:3).

FAIR is a set of guiding principles to make data Findable, Accessible, Interoperable and Reusable. (FORCE 11, 2017). Each principle consists of specific criteria and sub-criteria that should be fulfilled for characterizing the data FAIRness. These principles, criteria and sub-criteria are listed below and explained according to the information available from the Dutch Techcentre for Life Sciences (DTL) website[7].

2.6.1 The FAIR Data Principles

Findable: The data and metadata are easy to find by both humans and computers.

F1: (meta) data are assigned globally unique and persistent identifiers

In case of FAIR, identifiers mean a link on the internet (for example a URL), that resolves to a web page that defines the concept. The identifiers are useful for citation and reuse of data. But, besides the identifier per se, its meaning is also of great importance. Under F1, two conditions must be fulfilled: (1) it must be globally unique (which means that someone else could not reuse/ reassign the same identifier without, in so doing, referring to your data) and (2) it must be persistent (it takes time and money to keep links active on the Web; over time, links tend to get 'broken').

[7] https://www.dtls.nl/fair-data/fair-principles-explained/

F2: Data are described with rich metadata

Metadata should include rich information about the context, quality, condition or characteristics of the data. ***Rich metadata*** for FAIR implies that the publisher should not presume that knows who will want to use the data and for what purpose; information should be provided generously.

F3: Metadata clearly and explicitly include the identifier of the data it describes

Sometimes, metadata and data sets are separate files. The association between the metadata and the data file should be made explicitly by mentioning a dataset's unique persistent identifier in the metadata.

F4: (meta)data are registered or indexed in a searchable resource

The data repository, the source of (meta)data, should be discoverable. F1 – F3 will provide the core elements for fine grained indexing by some current repositories and future services.

Accessible: Limitations on the use of data, and protocols for querying or copying data are made explicit for both humans and machines.

A1: (meta)data are retrievable by their identifier using a standardized communication protocol

For most users of the Internet, the data are retrieved by clicking on a link. This principle states that FAIR data retrieval should be mediated without specialized tools or communication methods. So, clearly define who can access the actual data, and specify how. Some examples of standardized communication protocols used by data producers are: HTTP(S), SMTP, FTP and so forth.

A1.1: The protocol is open, free and universally implementable

The protocol used should be free (no-cost), and open (-sourced). In this way, it will be globally implemented to facilitate the data retrieval and thus anyone with a computer and internet connection will be able to access at least the metadata.

A1.2: The protocol allows for an authentication and authorization when required

This is a critical part of the FAIR Data. However, there is often misunderstanding about the "A" in FAIR. Accessibility is not directly meaning "Open" and "Free" data. In fact, heavily protected and private data can be FAIR. In many cases, users should create a user's account on a repository. This allows to authenticate the owner or the contributor of each data set and to potentially set user specific rights. Hence, this criterion will also affect the choice of the repository where someone will share the data. Some examples are: HMAC authentication, HTTPS, FTPS and so forth.

A2: Metadata should be accessible even when the data is no longer available

Since the maintenance costs for keeping data present online are high, data per se tend to degrade or disappear completely. When this happens, users end up wasting their time trying hunt data that might no longer exist. However, if metadata are stored, it is an easier and cheaper practice. A2 criterion, is related to the registration and indexing issues described in F4.

Interoperable: The computer can interpret the data, so that they can be automatically combined with other data. Data interoperability can be seen as the ragged edge of this long-term trend. However, data interoperation is a non-trivial problem and the "I" will require the most creative effort in making FAIR Data

I1: (meta)data use a formal, accessible, shared and broadly applicable language for knowledge representation.

Data should be exchangeable and interpretable by both humans and computers. For achieving so, it is preferred to use a language that is readable without the need of specialized or ad hoc algorithms, translators or mappings (these are characteristics of a dead language). Moreover, automatic findability from the side of computer systems should be achieved. For this to happen it is critical to use (1) commonly used controlled vocabularies, ontologies, thesauri (having globally unique identifiers; see F1) and (2) a good data model; a well-defined framework to describe the structure of the (meta)data

I2: (meta)data use vocabularies that follow the FAIR principles

The controlled vocabulary used to describe data sets needs to be documented and resolvable using globally unique and persistent identifiers. This documentation needs to be easily findable and accessible by anyone who uses the data set.

I3: (meta)data include qualified references to other (meta)data.

A "qualified reference" is a cross-reference that explains its "intent". The goal of this criterion is to create as much as possible meaningful linkages between (meta)data resources. More specifically, there is a need for specifying if one dataset builds on another data set, if additional data sets are needed to complete the data, or if complementary information is stored in a different data set.

Reusable: Data and metadata are sufficiently well described for both humans and computers, so that they can be replicated or combined in future research.

R1: meta(data) are richly described with a plurality of accurate and relevant attribute

This principle is related with F2. But here, the focus is not only on the labels that makes data easier to be found. The aim is that the user, machine or human, decides whether the data just found (F2) is useful in their context. For facilitating this decision, the data provider should provide not just metadata that allows discovery. The metadata should also include the context under which that data was generated (include for example experimental protocols, the manufacturer and brand of the machine or sensor that created the data, the species used and so forth). Moreover, plurality means that the data publisher should be as generous as possible with the information included in the metadata even though it seems that some of them are irrelevant.

R1.1: (meta)data are released with a clear and accessible data usage license.

"I" (Interoperability) principle was focused on the technical interoperability. Here, we talk about "legal" interoperability; the usage rights given to the data. Since, this principle asks for clear description of the licencing, the more automated search involves licencing considerations, the more important clarity of licencing status the data will be. Creative Commons is a licencing example that can be linked to data.

R1.2: (meta)data are associated with detailed provenance

The origin of the data should be known (see R1). However, it is also important to be aware of whom to cite in case of reusing the data and how the author may wish to be acknowledged. Also, information regarding who generated or collected the data, how the data has been processed or if the data has been published before and so forth, is considered of great importance for this criterion.

R1.3: (meta)data meet domain-relevant community standards

Since it is easier to reuse data sets that are similar (they are of the same type, organized in a standardized way and so forth), community standards or best practices for data archiving and sharing should be followed if existing. Publishing (meta)data in a manner that increases its use (ability) by the community is the primary objective of FAIRness. It is, however, important to note that quality issuers are not addressed by the FAIR principles. Reliability issues are not in the scope of these principles and the consumers are responsible for checking this issue.

2.6.1.1 The theoretical (conceptual) assessment of the INSPIRE's FAIRness

In this first phase, INSPIRE will be assessed on its FAIRness in a theoretical level. INSPIRE consists of several legislation and Technical Guidance documents where all the guidelines (on how the spatial data sets and services should be harmonized, be interoperable and be shared) are defined. In the meantime, FAIR aims in achieving a more efficient way of data availability and sharing by proposing 15 facets regarding the findability, interoperability, accessibility and reusability of datasets and services. In this step, it is investigated in what extend the INSPIRE as a concept is in line with the FAIR concept; we will evaluate if INSPIRE is compliant to the FAIR data principles, in a conceptual level. This conceptual investigation is distinguished of the Practical Assessment (see Section 2.6.1.2) that follows by means that, in this step no real data will be searched and evaluated on their FAIR-ness. We will focus, only, on the concepts of the Directive and the FAIR principles.

For assessing the level of compliance between the FAIR principles and the INSPIRE legislation, a rating system - the traffic-light system- which was introduced in the

assessment held by the 4TU.Research Data and consists of four rating categories will be used. There has been an adjustment to the categories of this rating system for fitting the purposes of this research. Thus, the four categories used in this assessment are the following:

1. **Complies Completely (CC):** when the FAIR principle is in line with the INSPIRE regulations (green colour)
2. **Almost Compliant (AC):** when INSPIRE is not completely in line with what FAIR principle states but still follows some of the FAIR demands. (orange colour)
3. **Failed to comply (F):** when INSPIRE doesn't follow at all the concept of the FAIR principle (red colour) and
4. **Unclear (U):** when it is not clear whether the FAIR principle is included in the INSPIRE regulations (light blue colour)

	Complies Completely	CC
	Almost Complies	AC
	Failed to comply	F
	Unclear	U

The results will be available under ***Appendix 4***.

2.6.1.2 The practical assessment of the INSPIRE's Geoportal FAIR-ness for the IMPP countries.

In this second phase, INSPIRE will be assessed in practice. INSPIRE data are made available to the public through the INSPIRE Geo-portal. For accessing the available marine data, the Discovery/Viewer Section of the portal will be used. A similar research was held by Abramic et al. (2018). However, there is an important difference between that effort and this research. As Abramic et al. (2018) notes "*The keywords were selected from a vocabulary of recognised keywords used by the geo-portal and translated in all EU official languages. The vocabulary was obtained from the INSPIRE Geoportal Operational Pilot development group of the EC Joint Research Centre (JRC). This resource is unpublished and contains a sub-group of keywords taken from official translations of the INSPIRE Directive and from the General Multilingual Environmental Thesaurus*". An unpublished source of keywords cannot be reused for other research purposes. Thus, there was a need for creating a vocabulary for answering the research questions. The terms of RQ2 will be used as keywords for searching the data. In cases when the keyword's meaning is too broad, a second keyword will be used to narrow down the results. For example, the keyword "species distribution" covers any kind of species such as marine species, animal species etc. Since we are interested only in the marine- related metadata, we will also use the keyword "marine" to receive only the marine relevant results for the species distribution.

INSPIRE Geoportal includes metadata records for all the EU countries. In this research, the three IMPP countries; the Netherlands, Germany and Denmark will be assessed. Each IMPP country will be assessed separately, by using of the Geoportal's "Origin" option. MSFD's spatial requirements are presented in tabular form under three Tables (see MSFD Annex III). For consistency with the Annex III, the same structure will be kept in the presentation of the results. Thus, three Tables will be created under Annex 4:

- Table 4.1i: INSPIRE marine- related metadata records for the 1st group of MSFD requirements that are registered in the Geoportal (in total and per IMPP country)

- Table 4-2a: INSPIRE marine- related metadata records for the 2nd group of MSFD requirements that are registered in the Geoportal (in total and per IMPP country)

and

- Table 4-2b: INSPIRE marine- related records for the 3rd group of MSFD requirements that are registered in the Geoportal (in total and per IMPP country)

In the report, a few representative examples will be included for supporting the analysis.

The next step is to assess the results by using the 15 facets of the FAIR data principles. The metadata records of all IMPP countries will be noted in the Table 4.3: How FAIR is INSPIRE Geo-portal. This table will include the following information: the MSFD theme they belong to, the origin (IMPP country), the metadata record type (spatial data, series, service or download service dataset) and the level of compliancy with each FAIR facet. For the compliancy assessment, the traffic-light system (as presented in **Section 2.6.1.1** "**The theoretical assessment of the INSPIRE's FAIR-ness"**) will be used. During the evaluation process each metadata record will be assessed for each of the 15 FAIR facets and will be ranked based on whether it is in line with the guidelines of each facet. The FAIR facets are analysed extensively in Section 2.5 In the table that follows, there is an example of the evaluation and rating process:

MSFD Theme	Term used	Country	Metadata record name	Metadata record type	FINDABLE				ACCESSIBLE				INTEROPERABLE			REUSABLE			
					F1	F2	F3	F4	A1	A1.1	A1.2	A2	I1	I2	I3	R1	R1.1	R1.2	R1.3
Species	Species Distribution + marine	Netherlands	CSW Nationaal Georegister (NGR): INSPIRE zoekdienst	Discovery service	F	CC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC

In the presented example an INSPIRE service is assessed. This service failed to comply with the facets F1 and F4 of the "Findable" principle. On the contrary, it was completely compliant with the facets F2 and F3. Thus, the facets F1 and F4 are assigned with an "F" (according to the traffic light system introduced in Section 2.6.1.1) and the facets F2 and F4 are assigned with "CC".

The INSPIRE rating process

The rating process of how FAIR is INSPIRE will be the last step. An example of the calculations follows where the values presented in the table below are only for explaining the process; they are not actual results.

Metadata record type		FINDABLE				ACCESSIBLE				INTEROPERABLE			REUSABLE			
		F1	F2	F3	F4	A1	A1.1	A1.2	A2	I1	I2	I3	R1	R1.1	R1.2	R1.3
1.	Discovery service	F	CC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
2.	View Service	CC	CC	AC	CC	AC	F	AC	U	CC	AC	CC	AC	CC	F	CC
3.	Download Service	CC	F	F	CC	AC	F	CC	F	CC	F	F	F	CC	AC	F
4.	View Service	AC	AC	F	CC	CC	CC	CC	U	F	F	CC	CC	AC	CC	AC
5.	Dataset	AC	CC	F	AC	F	CC	F	AC	F	CC	AC	CC	AC	CC	CC
6.	Dataset	CC	F	CC	F	F	CC	CC	F	F	CC	CC	AC	F	F	CC
7.	Dataset	AC	CC	F	F	CC	CC	AC	CC	F	CC	AC	CC	CC	AC	F
8.	Dataset	CC	U	F	F	CC	F	F	F	AC	F	F	F	F	F	F

Step 1: Count the number of metadata records for each assessed category.

There are four Services and four Datasets in this example.

Step 2: For each FAIR principle's facet count the number of CC, F, AC or U.

Calculations

The first three metadata records are services and for the FINDABLE principle were assigned the following:

Services (No= 4)

	FINDABLE			
	F1	**F2**	**F3**	**F4**
Completely Compliant	2	2	1	3
Almost Compliant	1	1	1	0
Failed to comply	1	1	2	1
Unclear	0	0	0	0

Step 3: For calculating the % rate of each Facet (F1, F2, F3 and F4), the number of records of each rating category (Completely compliant, almost compliant, failed to

comply and Unclear) is divided by the total number of records. The result of the division is multiplied by 100 and there comes the % rate.

Calculations:

(2 /4) * 100 = **50 % completely compliant** service metadata records with the F1

Where

2 = number of the service metadata records that were completely compliant with the F1

4= total number of service metadata records

This process is repeated for the other three traffic light system categories and the results are:

(1/4) * 100 = **25 %** service metadata records were **almost compliant** with the F1 facet

(1/4) * 100= **25 %** of service metadata records **failed to comply** with the F1 facet

(0/4) * 100 = for **0** service metadata records it was **unclear** if they were compliant with the F1 facet

Step 4: Similarly, the steps 1,2 and 3 are repeated for the facets F2, F3 and F4 and the resulting percentages are presented below:

	Services (No= 4)			
	FINDABLE			
	F1	**F2**	**F3**	**F4**
Completely Compliant	**50**	**50**	**25**	**75**
Almost Compliant	**25**	**25**	**25**	**0**
Failed to comply	**25**	**25**	**50**	**25**
Unclear	**0**	**0**	**0**	**0**

Step 5: The last step is the calculation of the total rate of each FAIR principle for each category of the traffic light system. More specifically, the aim is to find in what % the INSPIRE services are completely compliant to the FINDABLE principle etc. For achieving this, the rates of all facets for each category (as they are listed in the traffic light system in Section 2.6.1.1) are added, and the result is divided by the number of the facets of the FAIR principle.

Calculations:

% of completely compliant service metadata records to the FINDABLE principle

(F1 + F2 + F3+ F4)/ 4 = (50+ 50+ 25+ 75) /4= **50%**

The same process is repeated for the other categories and the results are the following:

Services
(No= 4)

	FINDABLE				
	F1	**F2**	**F3**	**F4**	**F**
Completely Compliant	50	50	25	75	50
Almost Compliant	25	25	25	0	18.75
Failed to comply	25	25	50	25	31.75
Unclear	0	0	0	0	0

The above steps will be repeated for all the FAIR facets of all the metadata records. The results will be presented in Tables that will be available under the Appendix 4, titled "Tables 4-4: How FAIR is INSPIRE Geo-portal- The rating process. Finally, some graphs will be created from the Tables of Appendix 4 which will summarize these results. The graphs will be used in the Analysis Section under the "Results and Analysis" Chapter.

Chapter 3. Results and Analysis

In this Chapter all the results of the three Research Questions are presented and discussed.

3.1 Research Question 1: Are the INSPIRE Data Themes able to support the MSFD on a conceptual level?

The first step of this research was to study the INSPIRE Directive and find to what extend it can support MSFD with spatial information. INSPIRE consists of thirty-four (34) Data Themes each one of which has a specific scope.

For this purpose, MSFD's requirements (as listed in Annex III), were matched to one or more relevant INSPIRE Data Themes. A similar effort is presented in the Marine Pilot Report. However, as it is stated in that report *"This is a first, coarse, relation and that further analysis at the spatial object level needs to be carried out as part of the pilot".* Furthermore, a new amended version of MSFD Annex III was published in May 2017. Consequently, in this research, this new version was used.

In MSFD's amended Annex III, all the requirements are grouped in three tables. Also, they are sub-grouped in Themes for a better understanding of the concept that they serve. In total there are:

- Three (3) themes for information related to the structure, functions and processes of the ecosystems (later also referred as "1st group of MSFD requirements"
- Three (3) themes for information related to the anthropogenic pressures on the marine environment matched to the ecosystem elements (later also referred as "2nd group of MSFD requirements) and
- Ten (10) themes for information related to the uses and human activities in or affecting the marine environment (later also referred as "3rd group of MSFD requirements)

For each INSPIRE Data Theme (IDT) there is an INSPIRE Data Specification (IDS) document available. An IDS includes information related to the specific Data Theme such as its scope, its definition, use cases and its spatial data in the form of spatial objects (mapped in UML models). Also, an IDS includes information regarding the conceptual relationship or thematic overlap of this Data Theme with other Data

Themes. The MSFD themes were matched to one or more INSPIRE Data Themes (Table 1). In this first step, the MSFD terms were used as a tool for understanding if the examined IDS could conceptually include relevant spatial information to the specific MSFD theme. In Appendix 2, a more detailed analysis of the correlation between MSFD's themes and INSPIRE Data Themes (IDTs) is presented. The analysis revealed that INSPIRE can support MSFD's requirements in a conceptual level since twenty (20) out of the thirty-four (34) IDTs appeared to include relevant spatial information to the MSFD concept.

Table 1: INSPIRE Data Themes that are expected to support MSFD's data requirements (as they are listed in the amended Annex III)

	MSFD Theme	**INSPIRE Data Theme**
Structure, functions and processes of marine ecosystems	Species	Species Distribution
		Habitats and Biotopes
	Habitats	Species Distribution
		Habitats and Biotopes
		Bio- geographical Regions
	Ecosystem, including food webs	Sea Regions
		Elevation
		Oceanographic geographical features
		Area Management/ Restriction/Regulation Zones and Reporting Units
		Species Distribution
		Agriculture and Aquaculture Facilities
Anthropogenic pressures on the marine environment matched to the ecosystem elements	Biological	Habitats and Biotopes
		Agriculture and Aquaculture Facilities
		Protected Sites
		Natural Risk Zones
	Physical	Sea Regions
		Natural Risk Zones
		Atmospheric Conditions and Meteorological Conditions

	Substances, litter and energy	Atmospheric Conditions and Meteorological Conditions
		Production and Industrial Facilities
		Energy Resources
		Geology
Anthropogenic pressures on the marine environment matched to the ecosystem elements	Physical restructuring of rivers, coastline or seabed (water management)	Land Cover
		Utility and Government Services
		Administrative Units
		Natural Risk Zones
		Sea Regions
	Extraction of non-living resources	Mineral Resources
		Production and Industrial Facilities
		Energy Resources
	Production of energy	Energy Resources
		Utility and Government Services
	Extraction of living resources	Agriculture and Aquaculture Facilities
		Protected Sites
	Cultivation of living resources	Agriculture and Aquaculture Facilities
	Transport	Transport Network
	Urban and industrial uses	Production and Industrial Facilities
		Utility and Government Services
	Tourism and leisure	N/A
	Security/defence	N/A
	Education and research	Environmental Monitoring Facilities

As mentioned before, during the process of matching, the MSFD requirements to the IDTs the IDSs were studied. The process of defining the terms, that was followed during the Glossary creation, enabled the better understanding of the concept and objective of each of the MSFD Themes. The matching of the MSFD requirements with the IDSs (as they were listed under the MSFD Themes) was based on both the scope of each IDS and on the definition of each requirement. The result was that most of the MSFD

requirements were matched to one or more IDSs (see Appendix 2). However, the process revealed that the concept of a few MSFD requirements could not, conceptually, fit to any IDS. The Tables 2, 3 and 4 that follows present all the MSFD themes with the corresponding requirements, in the form of terms, that failed to match with any of the IDSs. The MSFD Theme "Species" and "Substances, litter and energy" appeared to include the highest number of uncorrelated requirements. Nevertheless, these two Themes have also a high number of requirements that were matched to one or more IDSs. There were, however, MSFD Themes such as the "Tourism and Leisure" or the "Security and Defence" that include only the terms that failed to match with any IDS. This is an important finding which clearly indicates the deficiency of conceptual linkage of INSPIRE to these specific concepts.

Table 2: MSFD requirements of *"Structure, functions and processes of marine ecosystems"* that were not matched to any INSPIRE DS (see Appendix 1/Table 1-1)

MSFD Theme	Searched Term	Source of definition
Species	Age *structure*	GEMET
	sex structure	Other
	Fecundity	Other
	Survival rate	GEMET
	Mortality rate (death rate)	Other
	Species composition	Other
Habitats - Per habitat type:	Age structure of species	GEMET

Table 3: MSFD requirements of *"Anthropogenic pressures on the marine environment"* that were not matched to any INSPIRE DS (see Appendix 1/Table 1-2)

MSFD Theme	Searched Term	Source of definition
Biological	Microbial pathogens	Other
	Genetically modified species	Other
Substances, litter and energy	Organic matter	GEMET
	Synthetic substances	Other
	Non-synthetic substances	Other
	Radionuclides	GEMET
	Acute events	Other

Table 4: MSFD requirements of *"Uses and human activities in or affecting the marine environment"* that were not matched to any INSPIRE DS (see Appendix 1/Table 1-3)

MSFD Theme	Searched Term	Source of definition
Physical restructuring of rivers, coastline or seabed (water management)	Offshore structures	Other
Extraction of living resources	Fish (or selfish) harvesting	Other
	Plant harvesting	Other
Cultivation of living resources	Forestry	GEMET
Urban and industrial uses	Urban	Other

	Industrial	Other
Tourism and leisure	Tourism infrastructure	Other
	Leisure infrastructure	Other
	Tourism activities	Other
	Leisure activities	GEMET
Security/defence	Military operation	GEMET

Summarizing the findings of Research Question 1, INSPIRE can, conceptually, support a high extent of MSFD requirements. Even though there are some MSFD requirements that were not matched to any of the INSPIRE Data Specifications, for their majority there were one or more INSPIRE Data Specifications with a possible relevance.

3.2 Research Question 2: Is there semantic interoperability, on attributes level, between the INSPIRE data specifications and the MSFD data requirements?

Data interoperability is among the principal aims of INSPIRE. Semantic interoperability is one out of four interoperability types. For assessing the semantic interoperability between INSPIRE and MSFD, the meanings of both the MSFD data requirements and the INSPIRE attributes should be available. The INSPIRE spatial data are sourced in 34 Data Themes (as they are defined in Annex I, II & III of the Directive). The data are mapped in several UML models under the form of spatial objects with definitions, attributes etc. The INSPIRE data modelling was based on the D2.5 "Generic Conceptual Model" (D2.6_v3.0, p.8). MSFD's data requirements are defined in its Articles and are listed in MSFD Annex III under three main groups. This listing facilitates an initial understanding of the requirements. However, the requirements in their present format are not defined and their meaning is relatively broad. Consequently, they cannot be used for the semantics assessment. For being possible to assess the semantic interoperability of the two Directives, a vocabulary of defined requirements was created so that they could be used as keywords for searching related spatial data in INSPIRE. This vocabulary was entitled as "The Glossary of MSFD terms" and can be found under **Appendix 1.** Where available, synonyms to the terms were assigned. The primary source of definitions was the GEMET. In case where a term was not registered in the GEMET, secondary sources were used, such as the Technical Report from DCE No. 16 (which also includes some definition for the MSFD terms used in the Annex III) or the Cambridge dictionary. As for the synonyms, only Cambridge Dictionary was used.

The level of heterogeneity between the MSFD terms and the INSPIRE spatial data indicated the level of the semantic interoperability on attributes level. In **Appendix 3**, there is an analytical presentation of the results. In total, 168 MSFD keyword terms were searched in the IDSs (as they are presented in **Table 1**)**.** In many cases, the same keyword term appeared in two (or more) MSFD Themes. For instance, the keyword term "*habitat extent*"**,** appeared in both "Species" and "Habitat" MSFD Themes. This can be explained due to thematic overlap; both MSFD Themes are focusing on the

species and their living. In **Table 5**, there is a listing of how many terms were searched in each IDS. This number differs from the number of unique terms appeared in the research; i.e. the term "habitat" could be used as a keyword more than once. Another case that has been observed was that a keyword could be matched to more than one IDSs. From RQ1, where the conceptual matching occurred, there were some cases where two or even three MSFD data requirements were matched to more than one IDSs. Each IDS has a difference scope. Consequently, in cases where the same term was assigned to i.e. two IDSs, the term was considered as a unique keyword for the assessment of the semantic heterogeneity and interoperability. As it is, also, shown in Table 5, the majority of the MSFD keywords searched turned results; only for 21 out of the 168 keyword no related data was found in the IDSs. It is important to mention that the Glossary played a major role in this stage of the research. MSFD terms were "hidden" in the policy documents without being listed and defined. Thus, the creation of this Glossary facilitated the searching process and helped in drawing conclusions regarding the levels of semantic interoperability between MSFD and INSPIRE.

Table 5: Total number of MSFD terms used for searching in the IDSs. (see Appendix 2)

MSFD requirements group	MSFD Theme	No. of MSFD terms	No. of terms that turned results while searching IDSs	No. of terms that didn't turn results while searching IDSs
1st	Species	21	14	7
	Habitats - Per habitat type	19	18	1
	Habitats- Additional for pelagic habitats	5	5	0
	Ecosystems	43	43	0
2nd	Biological	20	18	2
	Physical	4	4	0
	Substances, litter and energy	13	8	5
3rd	Physical restructuring of rivers, coastline or seabed (water management)	7	6	1
	Extraction of non-living resources	12	12	0
	Extraction of living resources	4	4	0
	Cultivation of living resources	4	4	0
	Transport	4	4	0
	Urban and industrial uses	4	4	0
	Tourism and leisure	4	0	4
	Security/defence	1	0	1

	Education and research	3	3	0
	Total number	**168**	**147**	**21**

Analysis of the semantic interoperability between INSPIRE and MSFD

In the following Section, the assessment of the MSFD requirements is presented. A more detailed presentation of the results can be found under the Appendix 3. Tables 3-1, 3-2a and 3-2b).

Assessment of the semantic interoperability between the INSPIRE spatial data and the MSFD requirements for the structures, functions and processes of the marine ecosystem.

"Structure, functions and processed of marine ecosystems" is the 1st group of the MSFD data requirements and consists of four main MSFD Themes (see Appendix 3, Table 3-1) In the Figure 3, that follows, we can see the rates for the semantic interoperability between the IDSs and the MSFD requirements. It was expected that INSPIRE would be able to serve these requirements. However, in the majority of IDSs high levels of semantic heterogeneity were detected. The high levels of semantic heterogeneity are equal to low levels or absence of semantic interoperability. The "Elevation", "Area Management" and "Agriculture and Aquaculture Facilities" IDSs are representative examples where high levels of semantic heterogeneity were observed between the attributes and the terms/ keywords used for searching. Interesting is the significant rate of non- interoperable results in the "Species Distribution" and in the "Sea Regions" IDSs. A possible reason could be that the keywords used were not as accurate as needed for being matched correctly with possible relevant attributes.

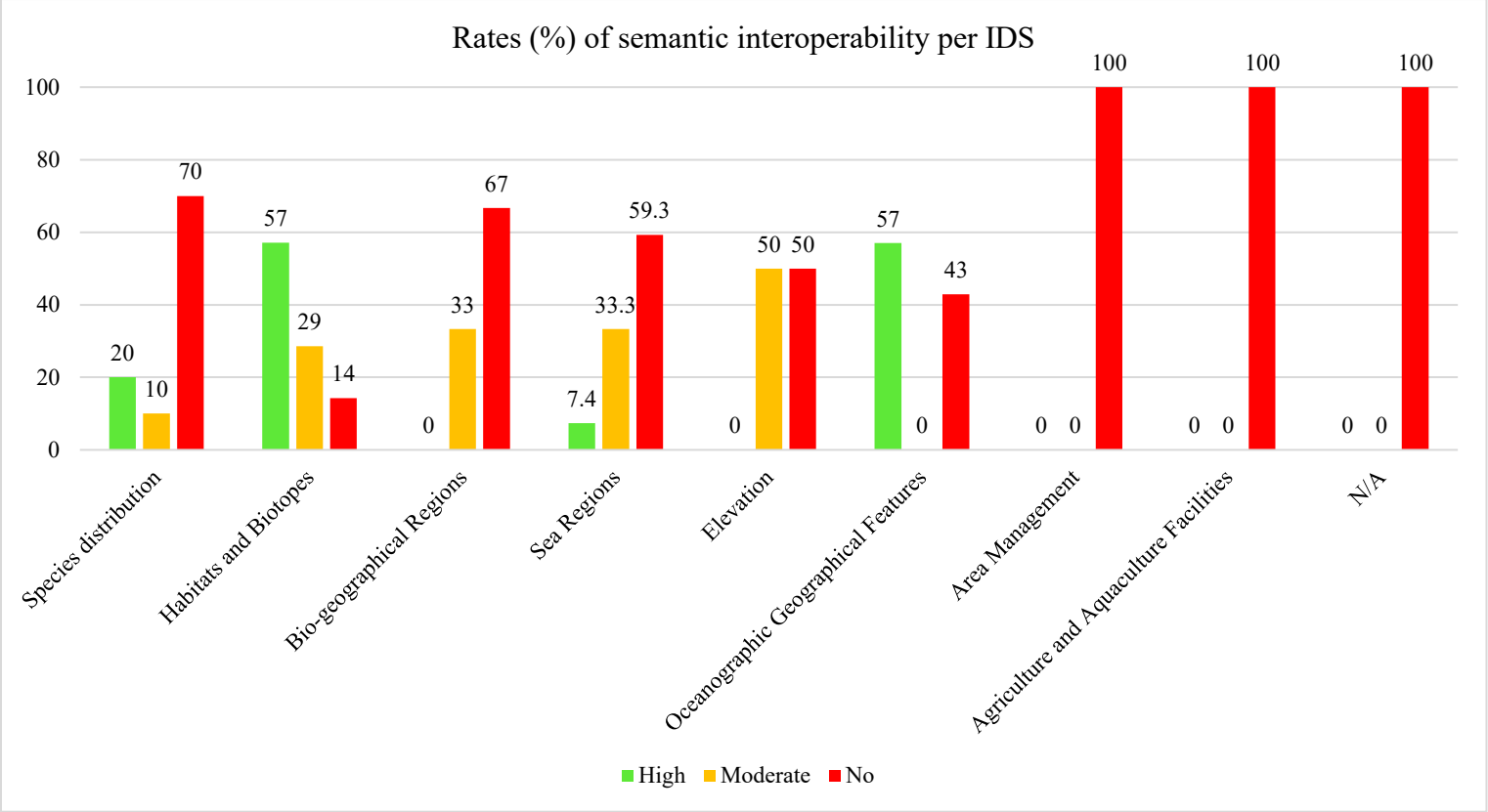

Figure 3:Rates (%) of semantic interoperability between the IDSs and the first group of MSFD data requirements (see Appendix 3/Table 3-1)

More than half of the searched keywords were found to be semantically interoperable with the "Oceanographic Geographical Features" and with the "Habitats and Biotopes" IDSs. The "Oceanographic Geographical Features" IDS (also referred as "OF") presents some peculiarities in relation to all the other IDSs. Here, the observed phenomena are not specified but they are described by the "observedproperty" attribute. INSPIRE recognized two different external vocabularies as suitable for identifying the observed properties of an "OF" observation. Thus, only in this case these external vocabularies were also used in the analysis. In cases when the keyword was found in the vocabulary, then it was rated as "High semantically interoperable". This explains why the "OF" rated higher among other IDSs. A more detailed analysis of these results can be found under Appendix 3.

Another category that was assessed included a number of data requirements that failed to match in any of the IDSs (see Section 3.1) These data requirements were searched in all the 34 IDSs. However, they showed high levels of semantic heterogeneity since they

didn’t match with any of the available attributes. Thus, they were all rated as 100% no semantically interoperable.

Concludingly, a total number of 8 IDSs were expected to include relevant attributes to the 1st group of the MSFD data requirements. The assessment, however, showed that 7 IDSs were not semantically interoperable with rates from 50% - 100% (in two cases). These rates underline the need of further investigation on whether they are results of unsuitable keywords – and thus to the Glossary of Terms- or due to deficiencies in the available INSPIRE attributes.

Assessment of the semantic interoperability between the INSPIRE spatial data and the MSFD requirements for the anthropogenic pressures on the marine environment.

The “Anthropogenic pressures on the marine environment matched to the ecosystem elements (part a)” is the 2nd group of the MSFD data requirements that was assessed. These requirements are sub-grouped in three MSFD Themes (see Appendix 3, Table 3-2a.). In total, 9 IDSs were found to serve this group’s requirements. For the search 37 terms were used; 30 terms were matched to one or more IDSs and for 7 no related information was found in any IDS. “Habitats and Biotopes” was the only IDS with 100% semantic interoperability. “Energy resources”, “Production and Industrial Facilities” and “Natural Risk Zones” showed some low rates in moderate interoperability between the terms and the INSPIRE attributes (50%, 25% and 25% respectively) (See Fig. 4).

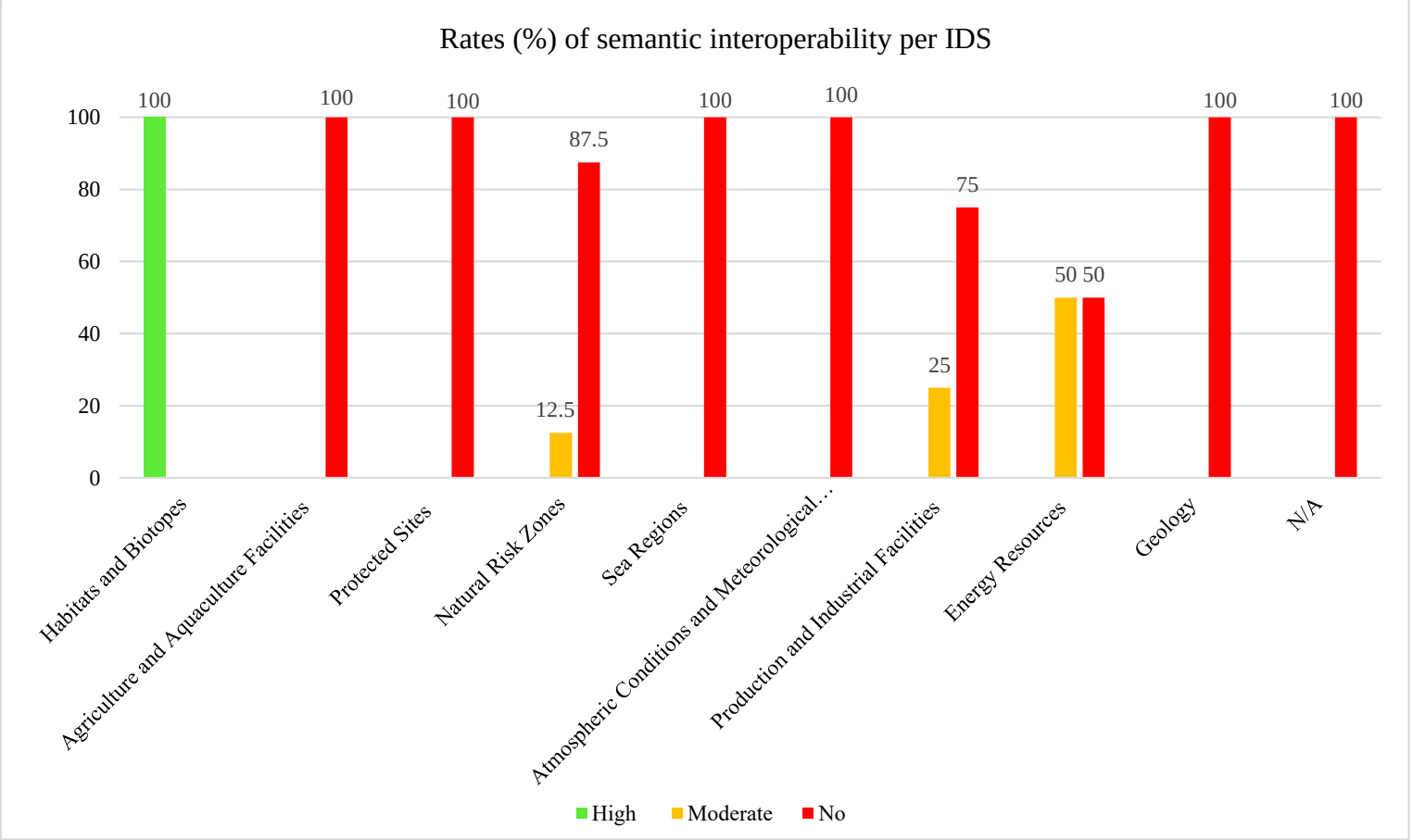

Figure 4: Rates (%) of semantic interoperability between the IDSs and the second group of MSFD data requirements (see Appendix /Table 3-2a.)

The majority of the IDSs (7 out of 9) resulted in very high or total rates of no semantic interoperability with the assessed MSFD requirements. A reason for the high levels of heterogeneity could be due to the chosen keywords; they were created for the purposes of this research and so they are not checked for their accuracy and suitability for such kind of analysis. As mentioned above, there were 7 terms that were not matched to any IDS and they showed high levels of semantic heterogeneity simultaneously. Thus, they were rated 100% for no semantic interoperability.

The results of the assessment for the second group of MSFD requirements showed that INSPIRE does not include relevant spatial information regarding the anthropogenic pressures that affect the marine ecosystems. As mentioned above, a potential reason could be the keyword selection. However, these high levels of naming heterogeneity reveal the need for an enrichment of the INSPIRE attributes or an expansion of the existing code lists and vocabularies with synonym terms.

Assessment of the semantic interoperability between the INSPIRE spatial data and the MSFD requirements for the *uses and human activities in or affecting the marine environment*

The "Uses and human activities in or affecting the marine environment" is the 3rd group of the MSFD data requirements that was assessed. In total, 43 terms were searched and for the 11 no information was available in any of the IDSs. These data requirements followed the same pattern as the ones of the other 2 groups that were not matched to any IDS: they scored 100% of no semantic interoperability. When assessing the 32 terms that were matched to one or more IDSs the following results were derived: In total, 12 IDSs were assessed with 5 being rated as high semantically interoperable. (see Figure 5)

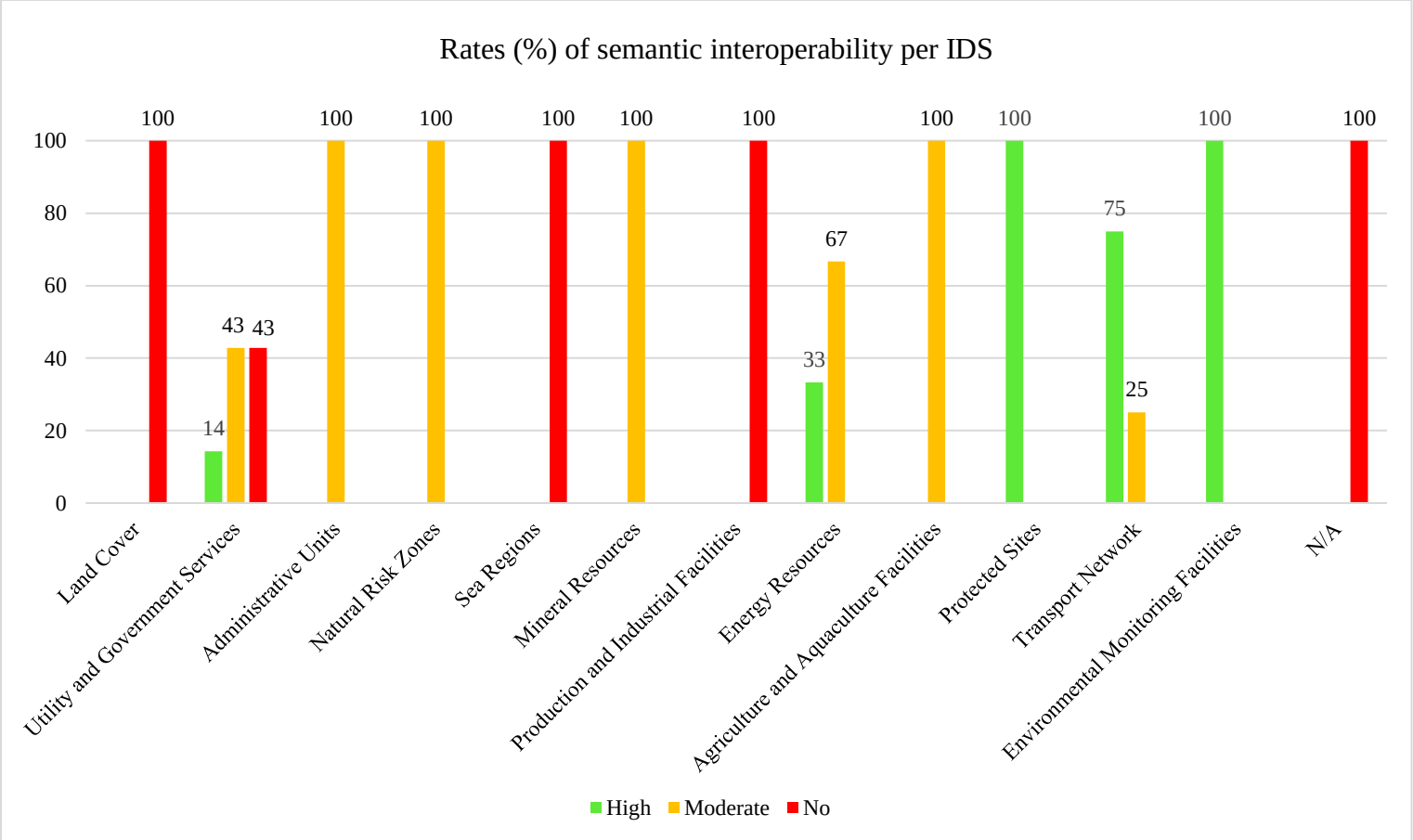

Figure 5: Rates (%) of semantic interoperability between the IDSs and the third group of MSFD data requirements. (see Appendix 3/Table 3-2b)

More specifically, the IDSs “Protected Sites” and “Environmental and Monitoring Facilities” were 100% semantically interoperable with the MSFD terms. For the “Energy resources” and “Utility and Government Services’ the rates for high semantic interoperability were 33% and 14% respectively. Interesting is the fact that 7 IDSs were rated as rated as “moderate”. The following IDSs showed moderate semantic interoperability: “Utility and Governmental Services”, “Administrative Units”, “Natural Risk Zones”, “Mineral Resources”, “Energy Resources”, “Agriculture and Aquaculture Facilities” and “Transport Networks” with rates 43%, 100%,100%,100%, 67%, 100% and 25% respectively. As it was defined in the Methodology, in case when a keyword doesn’t turn results, a synonym would be used, if available.

Concludingly, as presented in Figures 3, 4 and 5 moderate or even high levels of naming heterogeneity have been detected during the assessment process. These results point out the lack of INSPIRE in attributes or the naming heterogeneity of the already existing ones. All these situations affect the semantic interoperability in a negative manner. A general observation after the above assessment is that the Glossary was a key element when trying to detect the naming heterogeneity from the MSFD’s side. However, INSPIRE should enrich the spatial models with more attributes and include synonym terms for increasing the semantic interoperability between itself and any other source of information.

3.3 Research Question 3: Are the data findable, accessible, interoperable, and reusable to serve MSFD reporting?

"Research data management is a critical step in the research process for having organized data from its entry to the research cycle through to the dissemination and archiving of valuable results. It concerns four basic steps: i. how the data are created and the plan for its use, ii. the organization, structure and naming of data, iii. the keeping of data- make it secure, provide access, store and back up and iv. the finding of information resources, sharing with collaborators and more broadly, publish and get cited." (Whyte, A., Tedds, J. (2011) as cited in University of Leicester n.d) Universities are among the organizations that underline the importance of the existence of data policies. The data policy that Wageningen University & Research follows for the storage, archiving and registration of research data is based on leading principles in the area of research data management, such as the FAIR principles. (Wageningen University & Research, 2018)

The FAIR Data Principles were firstly introduced in January 2014, when an 'unconference' was organized titled 'Jointly designing a Data FAIRPORT' (an initiative of the Dutch Elixir node, in cooperation with the Netherlands e-Science Centre and the Lorentz Centre). The 25 participants were representatives of many different fields, and they agreed that "a global infrastructure for professional data publishing, discovery, exchange and re-use is essential for effective data-driven research." (Data FAIRport. 2014.). The result of this initiative was the FAIR data principles. FAIR stands for Findability, Accessibility, Interoperability and Reusability and is a set of principles that will facilitate the discovery, access, integration and analysis of scientific data and their associated algorithms and workflows. (THE FAIR DATA PRINCIPLES).

The 4TU Centre for Research data (4TU. Research Data), which is part of TU Delft, conducted a research that lasted from November 2016 until February 2017, focusing on the assessment of several European data repositories about their FAIR-ness; how closely existing archives are to meet the FAIR principles. Some of the repositories assessed were the Mendeley-Data, the Infrared Space Observatory, the SeaDataNet. (Dunning et al., 2017) This analysis was an informative guideline during this research. Also, the traffic light system, that enables colour coding according to the level of

compliancy with the FAIR facets, was adopted for this assessment. INSPIRE was assessed both theoretically and practically for its FAIR-ness level about the available marine data.

3.3.1 How FAIR is INSPIRE: Results of the theoretical assessment

For the theoretical evaluation, all the FAIR facets were contrasted to the INSPIRE regulations. In total, there are 15 FAIR Facets for which INSPIRE was assessed in theory. For this assessment, the INSPIRE regulations concerning the metadata of Datasets, data series and services (view, search and download) were studied. For the rating of the FAIR-ness level the traffic light system was used. (see Chapter 2. Methodology).

INSPIRE, theoretically, appeared to be fully compliant with most of the FAIR facets; only for 3 out of the 15 FAIR Facets INSPIRE was rated as "vague" or "unclear". (see Table 6). INSPIRE regulation documents provide a full guidance on how the metadata should be made available to the public. FAIR facet *"A2"* proposes that the metadata should be available even when the data are no longer available. INSPIRE was rated as "unclear" for this facet, because there is no clear reference in the documentation of what happens to the metadata in cases where the data is no longer available. Another facet for which INSPIRE was rates as "unclear" was *"R1.2: (meta)data are associated with their provenance"* Same as in A2, it was not, clearly, mentioned in the INSPIRE metadata regulations whether specific information about the origin of the metadata should be provided. According to INSPIRE, there should be a source (i.e. a link) with information about the provider. But, in many cases the provider is not the producer. Thus, this point is vague. The last FAIR facet that INSPIRE's compliancy was under discussion is the *"R1. Metadata have a plurality of accurate and relevant attributes"*. INSPIRE requires that *"Where applicable, capturing rules and associated criteria shall be specified for every spatial object type as part of an INSPIRE data specification in conformance with ISO 19131."* (D2.5_v3.4rc3.docx, p.105). However, there is still an indistinctness on whether the Data Specifications are harmonized so that consistency of data is finally achieved. In Annex B of the INSPIRE GCM about the consistency between data it is discussed that within the context of INSPIRE the consolidated model will include all INSPIRE data themes. The harmonization between the data is still something that needs to be clarified further. (D2.5_v3.4rc3.docx, p. 108-109).

Table 6**:** Level of compliancy of INSPIRE data with FAIR Data Principles (theoretical approach)

FAIR Data Principles	**FAIR Facets**	**INSPIRE Regulation for metadata of Data sets, Data Series and Network Services (View Services, Search Services and Download Services)**	**Level of INSPIRE Compliancy**
FINDABLE	**F1:** (meta)data are assigned a globally unique and eternally persistent identifier.	INSPIRE data are assigned with a Unique Resource Identifier	Fully compliant
	F2: data are described with rich metadata	Metadata are described according to a list provided in INSPIRE Technical Guidance documents	Fully compliant
	F3: (meta)data are registered or indexed in a searchable resource.	(See F2): INSPIRE Directive as regards the Network Services defines as searching criteria a list of metadata elements for data sets, data series and data services (discovery, view and download). (see Appendix 4, Table 4)	Fully compliant
	F4: metadata specify the data identifier.	Unique Resource Identifier is among the metadata elements that are available as searching criteria.	Fully compliant
ACCESSIBLE	**A1:** (meta)data are retrievable by their identifier using a standardized communications protocol.	HTTP protocol is used	Fully compliant
	A1.1: the protocol is open, free, and universally implementable	HTTP is open, free and universally implementable	Fully compliant
	A1.2: the protocol allows for an authentication and authorization procedure, where necessary.	The metadata provide users a URL for downloading their data. Depending on the type of data authentication or authorization may be needed	Fully compliant
	A2: metadata are accessible, even when the data are no longer available	No information available	Unclear
INTEROPERABLE	**I1:** (meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation.	GML (ISO 19136) and ISO/TS 19139 are promoted as the default encoding in INSPIRE.	Fully compliant
	I2: (meta)data use vocabularies that follow FAIR principles.	INSPIRE recommends the use of controlled vocabularies for assigning keywords to the metadata. Also, the GEMET is suggested for selection of at least two of the total keywords used.	Fully compliant

	I3: (meta)data include qualified references to other (meta)data.	A URL is provided that enables linkage with other information either for the data or for the resource.	Fully compliant
RE-USABLE	**R1:** meta(data) have a plurality of accurate and relevant attributes.		Almost Compliant
	R1.1: (meta)data are released with a clear and accessible data usage license.	INSPIRE recommends that for detailed information about the licensing of the resource, a link to a license type (e.g. http://creativecommons.org/licenses/by/3.0), a website or to a document containing the necessary information shall be provided. (TG_Metadata_ISO19139_2.0, p27)	Fully compliant
	R1.2: (meta)data are associated with their provenance.	There was no relevant information to this facet's requirements.	Failed to Comply
	R1.3: (meta)data meet domain-relevant community standards	Analytical information about best practices for registers and registries can be found in the "Best Practices for registers and registries & Technical Guidelines for the INSPIRE register federation" document	Fully compliant

The theoretical assessment resulted in a very high level of INSPIRE "FAIR"-ness. Most of the FAIR guidelines are in line with the INSPIRE regulations. Thus, a similar result of FAIR-ness is expected in the evaluation of the INSPIRE Geoportal, that follows.

3.3.2 How FAIR is INSPIRE: results of the practical assessment

For assessing how FAIR is INSPIRE in practice, the INSPIRE Geoportal was used. In the Geoportal, the metadata records of all the EU Member States are registered. Since this research is focusing on the MSFD spatial data requirements, only the marine-relevant records of the Geoportal were of our interest. Moreover, there has been a selection of specific countries that were assessed: the Netherlands, Germany and Denmark were the countries for which INSPIRE will be evaluated. These countries participated in the IMPP, which was also used as a guide in this research.

3.3.2.1 Available INSPIRE marine-related data of the IMPP countries (NL, DE and DK) in the INSPIRE Geoportal

In total, there are 462.837[8] metadata records in the INSPIRE Geoportal and can be accessed via the Discovery/View service. There is a diversity among the registrations of the EU Member States. Focusing on the three countries participating in this assessment, Germany has the highest number of the registered metadata followed by the Netherlands. Denmark, however, has a significantly low amount of registrations (see Table 7). This lack of registrations could reflect potential difficulties in the implementation of INSPIRE.

Table 7: Metadata records of the IMPP countries in the INSPIRE Geoportal (see Appendix 4)

IMPP Country	No. of metadata records	% of metadata records in the INSPIRE Geoportal
Netherlands	2800	0.6
Germany	93924	20
Denmark	900	0.2
Total	97624	21

[8] The INSPIRE Geo-portal was accessed on January 2018.

In total, 129 terms (or combination of terms) were searched in the INSPIRE Geoportal. The results diverse again: the Netherlands has 58 marine-related metadata records, Germany has 105 and Denmark has 3 (See Table 8). Although the number of resulting metadata records is low, we can see that they follow a similar pattern as the results of Table 7. Germany, which has the highest number of total registrations among the three countries has, also, the highest number of marine-related records. The same occurs for the Netherlands and Denmark. Subsequently, these significant differences among the records, are pointing out that any future comparison of the countries by means of their FAIR-ness would be meaningless.

The analysis revealed that 97624 metadata records were available in the INSPIRE Geoportal for the IMPP countries which represent the 21% out of the total registrations. When focusing on the results for the IMPP countries, only 166 metadata records, which represents the 0,17% of the total, are related to the marine domain (58 metadata records for the Netherlands, 105 metadata records for Germany and 3 metadata records for Denmark) (see Table 8). In the study of Abramic et al. (2018), it is stated that the INSPIRE Geoportal contains only a 0,8% of related to the marine domain records. Although Abramic et al, studied the metadata records for all the EU countries, the rate remained low. The low rate of the IMPP countries' assessment together with the results of Abramic's study, reveal the gaps in the data availability process followed by the countries.

Table 8: Marine- related INSPIRE metadata records of the IMPP countries (as described under the MSFD themes). (see Appendix 4)

MSFD Theme	No. of MSFD terms used	Total number of records/ terms	No of metadata records for:		
			Netherlands	Germany	Denmark
Species	12	349	2	0	0
Habitats - Per habitat type	15	986	0	6	0
Habitats- Additional for pelagic habitats					
Ecosystems, including food webs	29	4987	35	37	1
Biological	14	283	0	0	0
Physical	3	1	0	0	0
Substances, litter and energy	13	196	0	2	0
Physical restructuring of rivers, coastline or seabed (water management)	7	30	0	23	0
Extraction of non-living resources	5	3	0	0	0
Production of energy	4	107	0	0	0

Extraction of living resources	4	877	0	14	1
Cultivation of living resources	7	1745	21	22	1
Transport	4	245	0	1	0
Urban and industrial uses	4	99	0	0	0
Tourism and leisure	4	3	0	0	0
Security/defence	1	0	0	0	0
Education and research	3	12	0	0	0
Total	**129**	**9923**	**58**	**105**	**3**

INSPIRE metadata are made available under five categories: datasets, series, services, layers and download service spatial data sets. In their vast majority, the results were spatial data sets, followed by layers and services and a few series (Table 6.) Interesting, though, is the low rate of download services which covered only the 4.8% of the total records. Abramic et al (2018), underlined that by the time when that research was conducted there were no download service data sets available related to the marine domain. However, he notes that this lack doesn't mean that the download services do not exist but that there could be "hidden" in the metadata as a link. Thus, the appearance of the download service data sets in the search results reflects the improvement of the INSPIRE Geo-portal in the way that they can be discovered by the user.

Table 9: INSPIRE marine-relevant metadata records of IMPP countries per category (IMPP)

INSPIRE metadata category	**No of marine-related metadata records per category**	**Rate (%) of marine-related metadata records per category**
Spatial Data Set	73	43.9
Series	4	2.4
Layer	46	27.7
Services (Discovery, View, Download)	35	21
Download Service Spatial Data Set	8	4.8

All these marine-related metadata records of Table 9 were assessed according to the FAIR principles. The results of this assessment are presented in the following Section.

3.3.2.2 FAIR Principles practical assessment results.

Each of the FAIR principles was studied separately and the results of this assessment are discussed below. This assessment is a follow-up to the theoretical evaluation of Section 1.3.1. In total, 166 metadata records were analysed. For evaluating the compliancy level of the marine-related metadata, the traffic-light system was used (See Chapter 2. Methodology). The assessment begins with a brief explanation of each FAIR Principle's concept. Then, the overall compliance rates of the INSPIRE metadata records to each Principle's facets, are presented. Based on these rates, the INSPIRE metadata categories with the lowest rates are selected and possible reasons that led to these results are explored. Finally, it is discussed how FAIR is INSPIRE based on these results. As analysed in Section 3.1.2.1 the INSPIRE Geoportal includes the metadata records for all the 30 EU Member States. This research focused on three countries, whose registered metadata represent the 21% of the total (see Table 7). Consequently, the results and the conclusions drawn for INSPIRE are expressed in this regard and so does the assumption about how FAIR is INSPIRE. Finally, the colours assigned in the different facets and which are presented in the figures are based on the colours of the traffic- light system: completely compliant with green, almost compliant with orange, failed to comply with red and unclear with light blue (see also Section 2.6.1 The FAIR Data principles). There is a detailed presentation of the rating process followed which can be found under Appendix 4 in the Section Tables 4-4: How FAIR is INSPIRE Geo-portal- The rating process. There, all the results of the five metadata records categories are listed and the rates for their levels of compliancy with each FAIR facet is presented.

"Findable" Principle

The "Findable" principle was analysed first. This principle consists of three facets: F1, F2 and F3 (see Section 2.6.1 The FAIR Data Principles). Most of the datasets, series and download service spatial datasets were assigned a unique identifier (see FAIR facets F1 and F3) and consisted of a rich list of metadata information (see FAIR facet F2). These three categories scored higher than 90% with series to be the category that complies completely (see Fig.6). On the contrary, the layers and services scored under 50%. INSPIRE doesn't require a unique identifier for the layers and services. Thus, the

facets F1 and F3 where assigned as “Failed to comply” and the percentages are affected respectively.

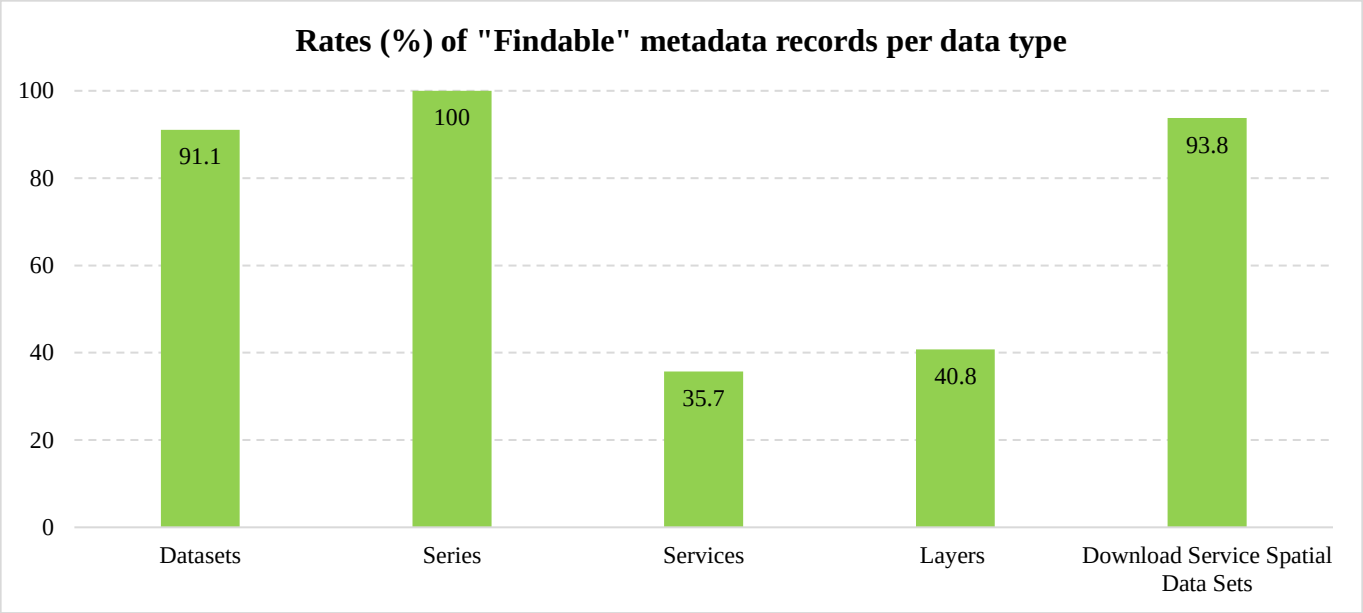

Figure 6: Percentages of all the “Findable” facets per data type that were completely compliant (CC) (see Appendix 4/Tables 4-4)

Less than half of the analysed Services and Layers, appeared to be fully compliant with the “Findability” principle; the 35.7 % of the Services complied completely and the 50% failed to comply (Fig.6). Similar results were derived from the analysis of the Layers records; the 40.8 % was fully compliant and the 32.6% failed to comply. In both cases, there were no unclear points in the analysis, so the “Unclear” rate was 0. The numbers indicate that in the cases of the services and the layers, INSPIRE and the FAIR guidelines were not in line for some of the Findable facets.

Services failed to comply 100% for the facets F1: (meta) data are assigned globally unique and persistent identifiers and F4: (meta)data are registered or indexed in a searchable resource. “If the resource is a spatial data service, this metadata element identifies, where relevant, the target spatial data set(s) of the service through their unique resource identifiers (URI)” (OJ L326, 4.12.2008, p.15). However, in most of the cases no identifier was found in the services. (Fig.6) Thus, these two facets were rated as “Failed to comply (or “F”). On the contrary, for the layers the existence of a unique identifier is recommended by the INSPIRE Regulations. In the INSPIRE regulation (see Table 3), it is stated that the INSPIRE data should be assigned with a Unique

Resource Identifier (in line with F1) and that a Unique Resource Identifier is among the metadata elements that are available as searching criteria. (in line with F4). However, 63% of the layers failed to comply with the F1 facet and 67.4% failed to comply with the F4 facet (Fig.3).

For the facet F2: Data are described with rich metadata, the services were rates as 42.9 % of being fully compliant (Fig.7) and the layers were rates as 100% almost compliant (Fig.8). A possible reason for these results could be the rating of each metadata record was based on the list of elements presented in Table 4 (Appendix 4). All the metadata record that missed an element, or more, were rated as "almost compliant". Thus, based on this strict assessment the result is that all the examined layers were missing one or more elements. The same occurred for the services. The percentages could be different if during the assessment process, a methodology was set on how a record with missing elements should be assessed or about which of the listed elements are more important for the richness of the record.

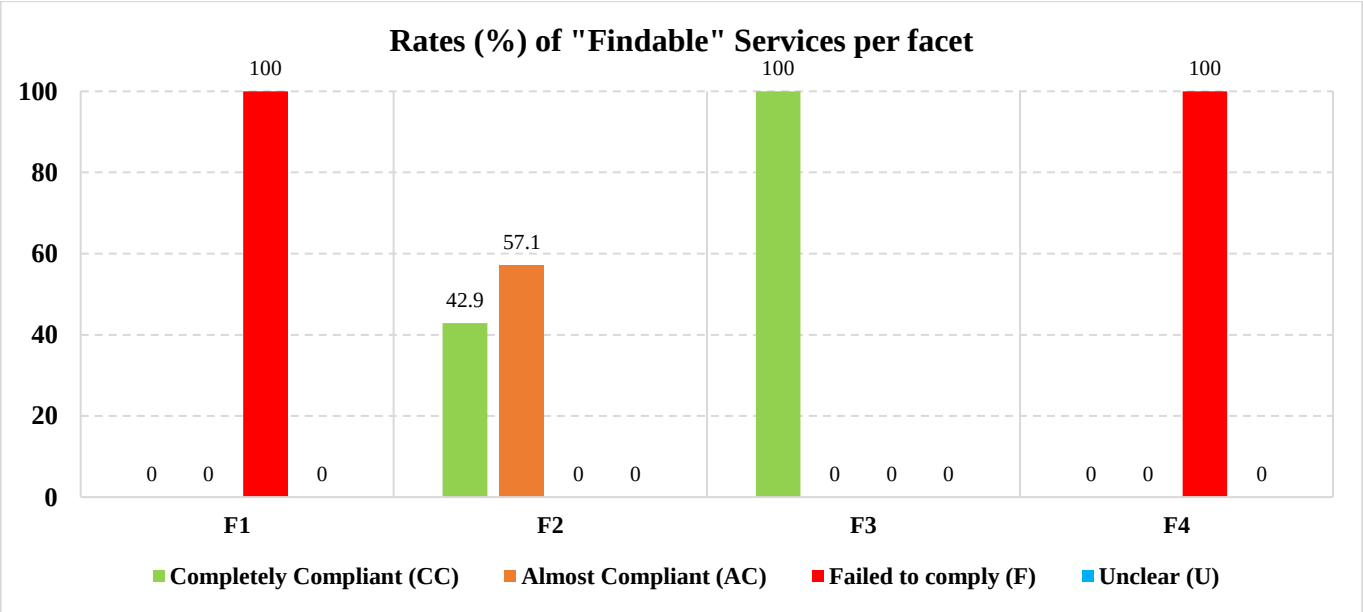

Figure 7: Rates for "Services" metadata records that were Completely Compliant (CC), almost compliant (AC), failed to comply (F) or their compliancy was Unclear (U). (see Appendix 4/Table 4-4c)

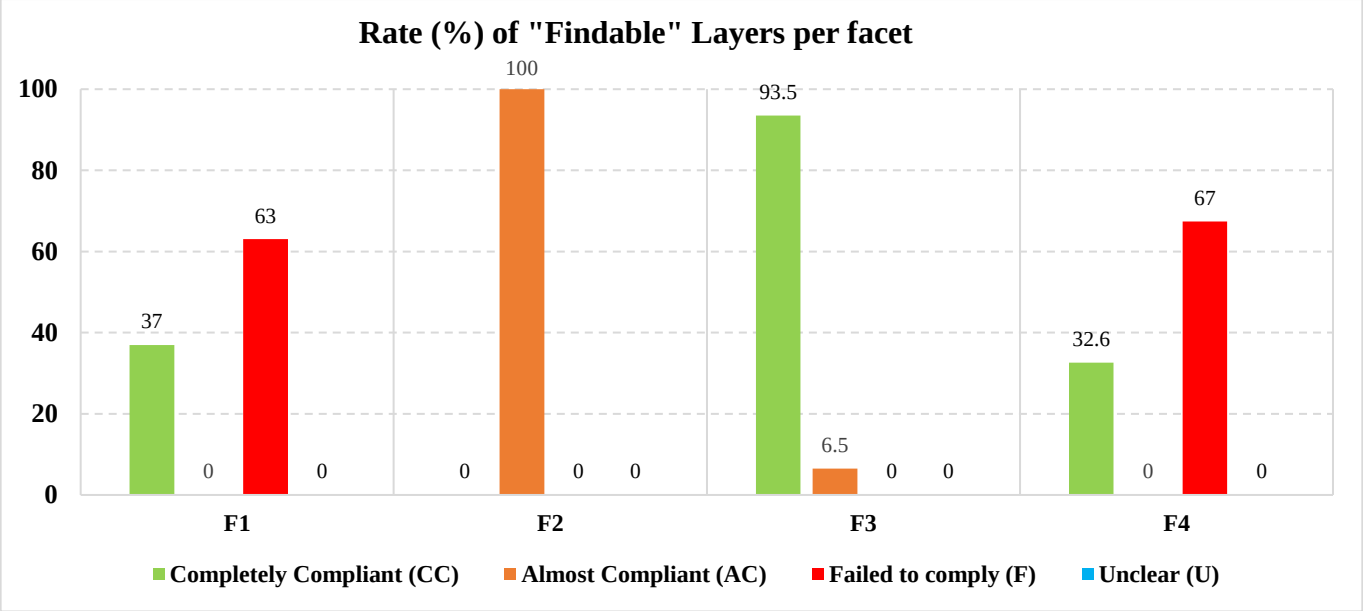

Figure 8: Rates for “Layers” metadata records for all the Findable facets (F1, F2, F3 and F4) (see Appendix 4/Table 4-4d)

“Accessible” principle

The “Accessible” principle deals with concepts such as: a. How retrievable the data can be by their unique identifier, using standardized protocols i.e. HTTP or HTTPS (A1), b. if these protocols are open and free (A1.1), c. whether there is the need for authentication by the user i.e. by creating an account for accessing the data (A1.2) and d. if the user can access the metadata, even if the data are no longer available (A2).
As it is presented in Figure 10 below, all records scored satisfactorily in this assessment. Services and layers were, again, the categories with the lowest ratings. Almost, half of the layers (55.4 %) and services (61.4%) were completely compliant. Series and download service spatial data sets scored a 75%, which brings them to the first place in the rank and in the second place we find the datasets with 72.9%.

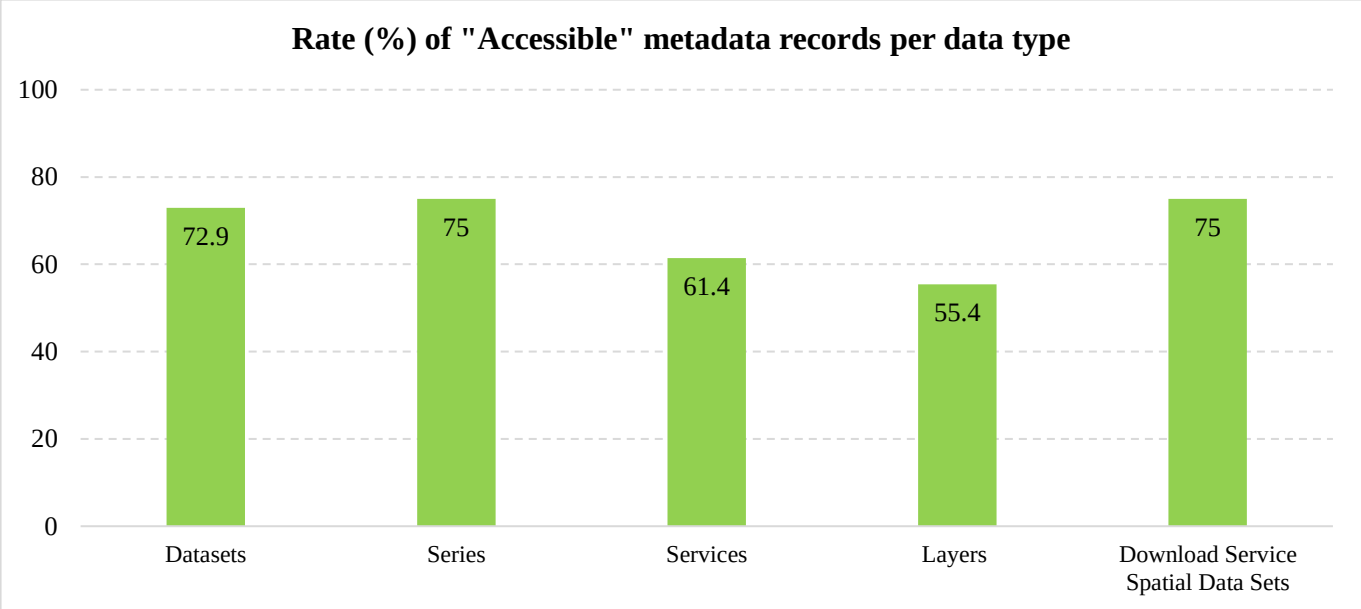

Figure 9: Percentages of all the “Accessible” facets per data type that were completely compliant (CC) (see Appendix 4/Tables 4-4)

The rates of services and layers appeared to be the lowest. By analysing the results of each category, we can see that Facets A1, A1.1 and A1.2 were relatively high for both categories; services rated an average of 73.9 % for the three above mentioned facets and layers rated an average of 82% respectively. However, for Facet A2: Metadata should be accessible even when the data is no longer available both categories were

rated as “Unclear” (Fig.9 and Fig.10). By means of rating, Facet A2 was rates as “Unclear” for all the categories. Thus, all the ratings were influenced by this Facet. INSPIRE doesn’t provide specific information on what happens with the metadata in case the data are no longer available. Neither in the INSPIRE Technical Guidance documents nor in the INSPIRE Legislation itself, there is a mentioning on such kind of cases. Finally, as for the Facets A1, and A1.1, in cases where there was no Unique Identifier (F1), the A1 failed to comply and so did A1.1 too.

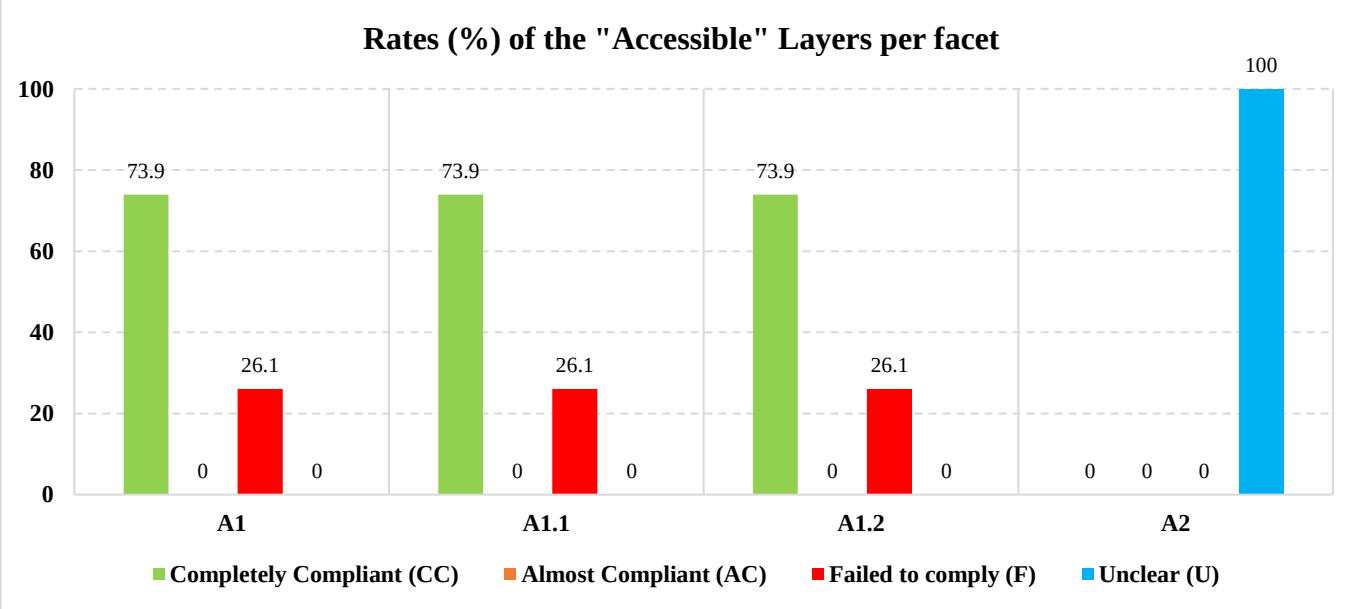

Figure 10 : Rates for the “Layers” metadata records for all the Accessible facets (A1, A1.1, A1.2 and A2) (see Appendix 4/Table 4-4)

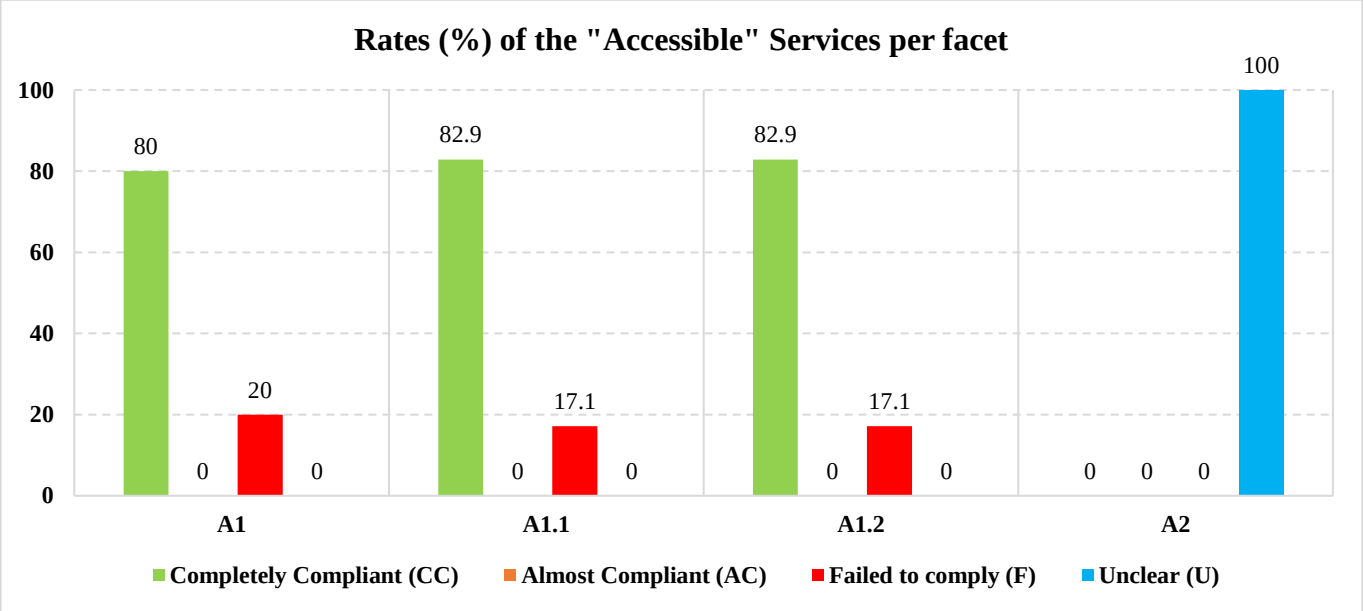

Figure 11: Rates for the "Services" metadata records for all the Accessible facets (A1, A1.1, A1.2 and A2) (see Appendix 4/Table 4-4c)

"Interoperable" principle

For being interoperable according to FAIR, the data should be exchangeable and interpretable by both humans and computers and this can be achieved if they are written in a readable language i.e. without the need of algorithms (I1). Moreover, controlled vocabularies of the data should be available including persistent and unique identifiers (I2) together with linkages of the data with other metadata sources; specify, for example, if a dataset is built upon another dataset (I3). INSPIRE data were assessed for all the above-mentioned criteria. Series were completely compliant to this FAIR principle (100%). Datasets and Services followed with 97.3% and 88,6% respectively. Layers were 67% fully compliant making them again the lowest rated category. Interesting is, also, the relatively low percentage (in comparison with the datasets, series and services categories) of the download service spatial data sets records; a 70.8% of was fully compliant.

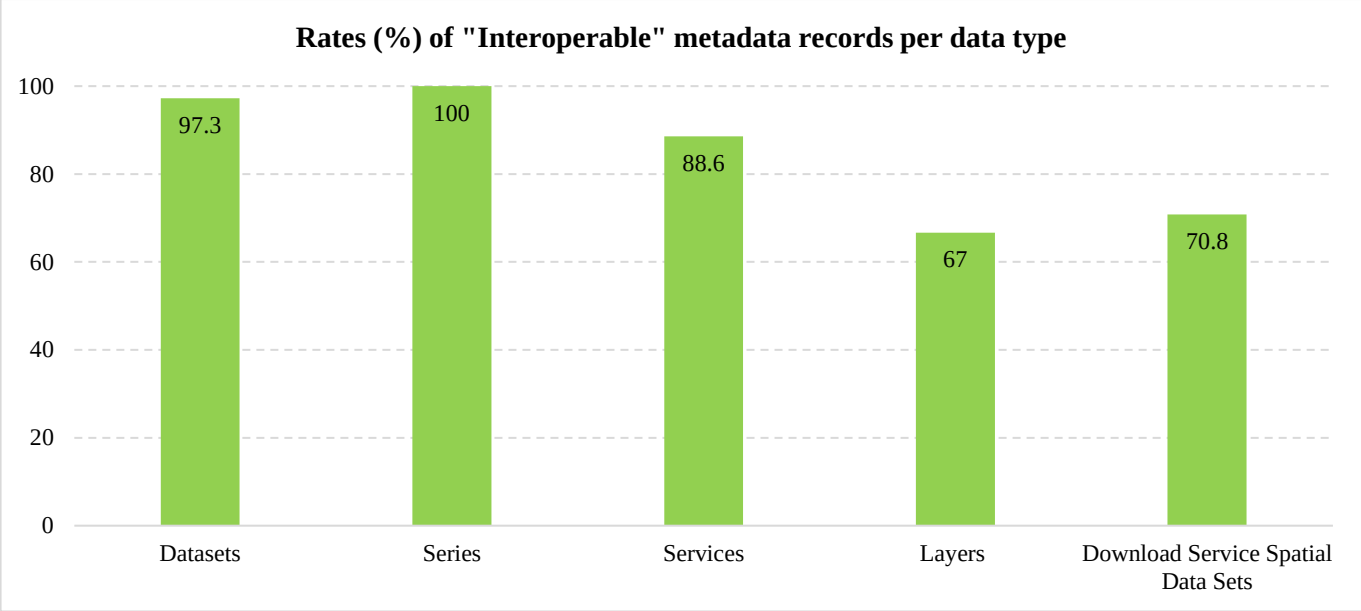

Figure 12: Percentages of all the "Interoperable" facets per data type that were completely compliant (CC) (see Appendix 4/Tables 4-4)

Layers were fully compliant with facets I1 and I3. This means that all the assessed records of this category were available in a readable language (I1) and that linkages with other sources were available. The overall rate was affected by the facet I2 for which all the records were rated as "Failed to comply". INSPIRE recommends the use of controlled vocabularies for assigning keywords to the metadata. Also, the GEMET is suggested for selection of at least two of the total keywords used. However, none of the Layer records fulfilled this requirement in practice and thus they were rated as that they failed to comply with this facet.

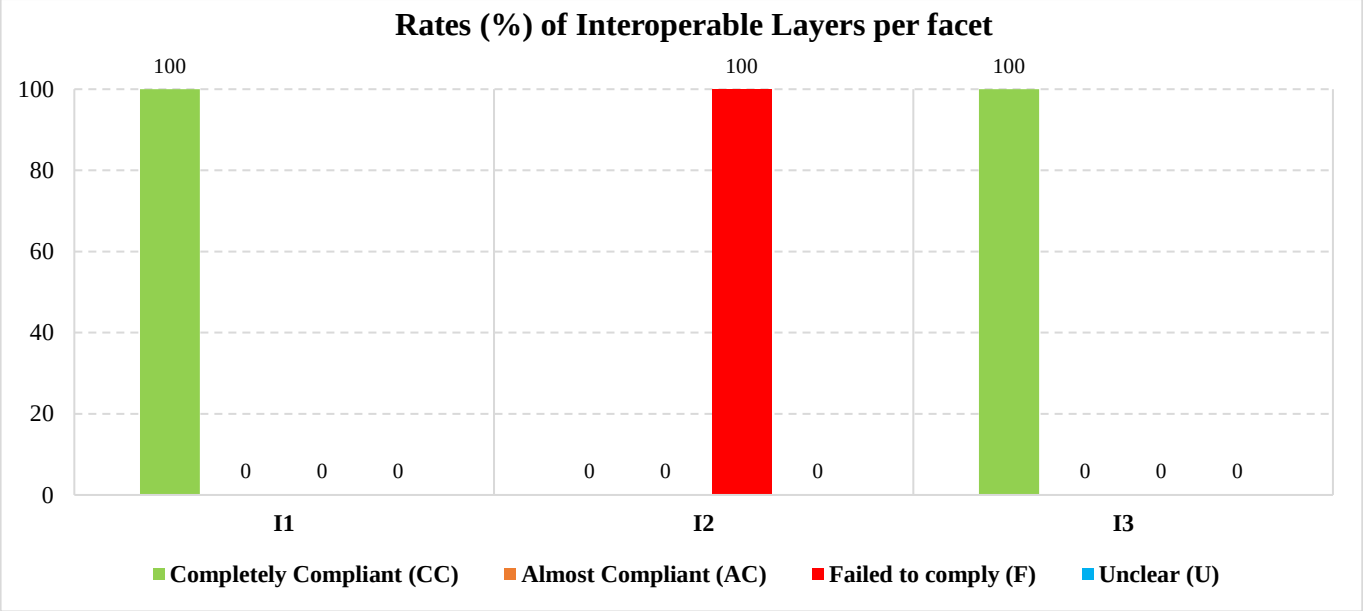

Figure 13: Rates for the "Layers" metadata records for all the Interoperable facets (I1, I2 and I3) (see Appendix 4/Table 4-4d)

In the case of the Download Service Spatial Datasets, the relatively low overall rate is due to the high percentage of the records that "failed to comply" with the I2 FAIR facet. Same as with the Layers, for the plurality of the records there was no Unique Identifier available and the keywords section was either empty or was not using keywords from a controlled vocabulary i.e. the GEMET. As it has already being noted, INSPIRE recommends the use of Controlled Vocabularies and Unique Identifiers. However, in practice many of the data were not conformant with these recommendations.

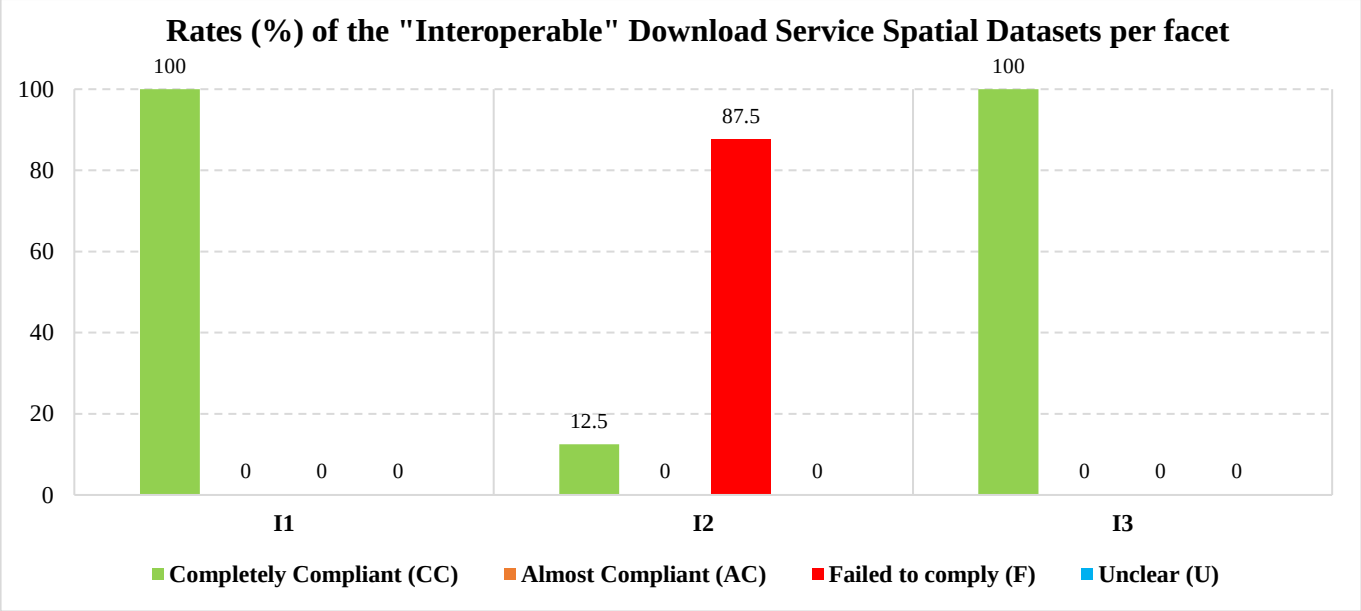

Figure 14: Rates for the “Download Service Spatial Datasets” metadata records for all the Interoperable facets (I1, I2 and I3) (see Appendix 4/Tables 4-4e)

“Re-usable” Principle

“Re-usability” was the last FAIR principle that the INSPIRE data was assessed for. The results follow a similar pattern by means of ratings with the other Principles; datasets and series scored the highest rates with 97.3% and 100% respectively. Series were rated high as completely compliant (88.6%) (see Figure 15). Download service spatial datasets were, also, rated a quite high percentage (70.8%). Layers, on the contrary, scored lower than the other categories; they were rated as 67% completely compliant.

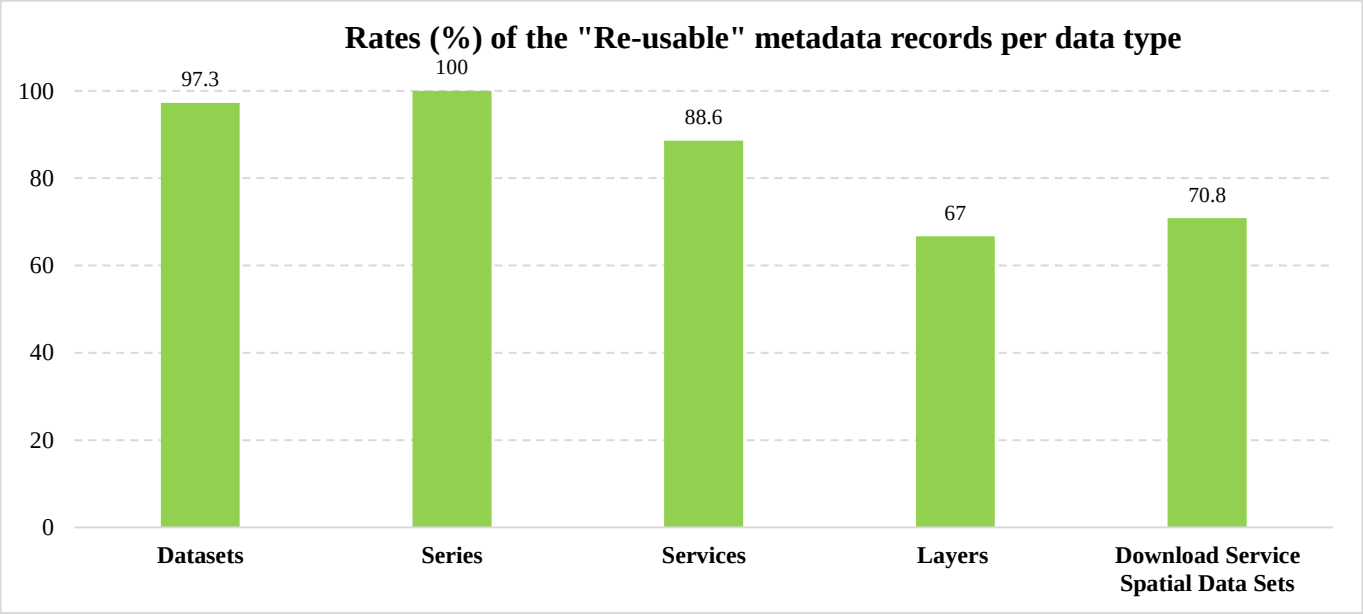

Figure 15: Percentages of all the “Re-usable” facets per data type that were completely compliant (CC) (see Appendix 4/Tables 4-4)

The ratings for the Re-usability facets of the layers are presented in Figure 11. All the assessed layers were rates as “almost compliant” with the facet *R1: meta(data) are richly described with a plurality of accurate and relevant attribute*. As it is described in the Methodology, the facet R1 is related with the F2 facet, where the data should be assessed about their usefulness. For concluding whether the data is useful to the user, the metadata should contain information about the context under which the data were generated by including i.e. experimental protocols or other information about the instruments that were used for gathering. There is a list of metadata elements, regarding INSPIRE, that should be present (see Table 4, Appendix 4) where none of this information is included. Layers failed to comply, in a vast majority, for the R1.1 facet: (meta)data are released with a clear and accessible data usage license. INSPIRE

recommends that for detailed information about the licensing of the resource, a link to a license type (e.g. http://creativecommons.org/licenses/by/3.0), a website or to a document containing the necessary information shall be provided. (TG_Metadata_ISO19139_2.0, p27). Only a 2.2% of the records included a link to their usage licence (i.e. CC).

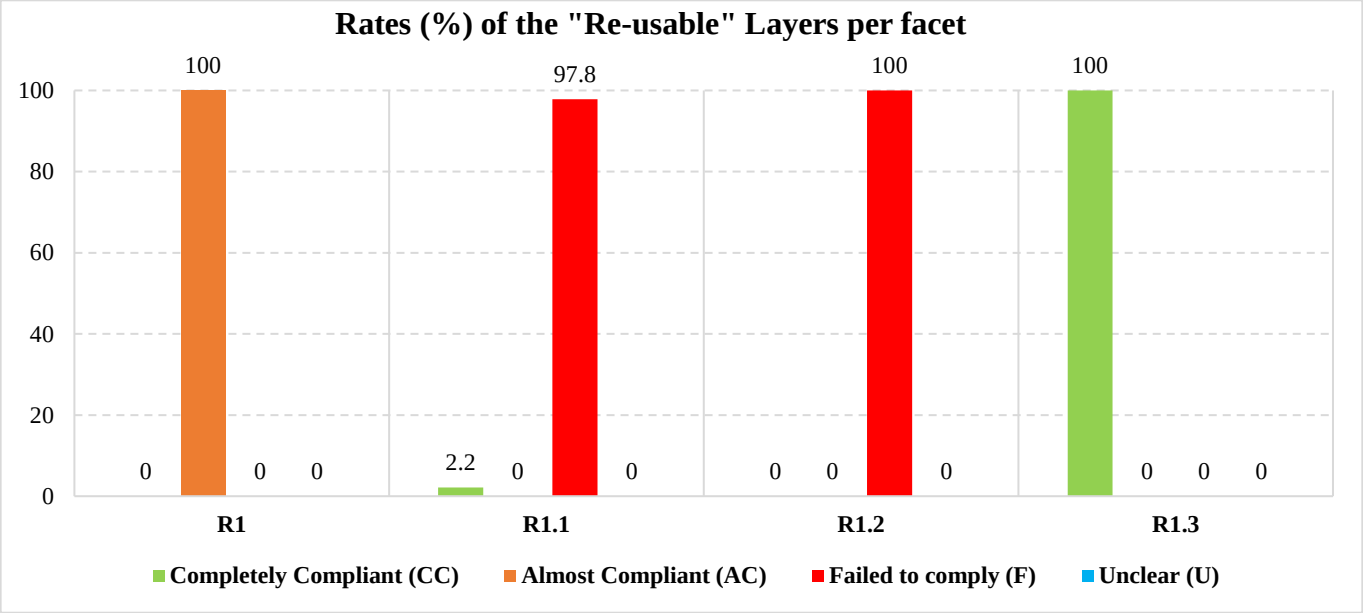

Figure 16: Rates for the "Layers" metadata records for all the Reusability facets (R1, R1.1, R1.2 and R1.3) (see Appendix 4/Table 4-4d)

All the assessed layers, also, failed to comply with the facet R1.2: (meta)data are associated with their provenance. Facet R1.2 is linked with the facet R1 which was also linked with facet F2. The origin of the metadata should be known (R1) and they should be explained with rich metadata (F2). Here, details about the author should be provided in case of data reuse together with information about how the data were generated or collected and how they have been processed or if they were published again before (R1.2). If we go back to "Findable" principle, INSPIRE metadata records were rated as 100% "almost compliant" for the facet F2 and for the facet R1 they were all rated as "almost compliant". As it seems, the facet R1.2 itself and the other two facets that it is related were proved to be a challenge for the INSPIRE layers to comply with.

On the contrary, all layers were completely compliant with the facet R1.3: (meta)data meet domain-relevant community standards. For this facet, all the assessed metadata were rated as completely compliant since INSPIRE used standards such as ISO and

OGC for data archiving and publishing. Moreover, as it is noted in Table 3, analytical information about best practices for registers and registries can be found in the "Best Practices for registers and registries & Technical Guidelines for the INSPIRE register federation" document.

In the case of the Download Service data sets, the results are following a similar pattern to the layers. The one and only difference is that download service data sets were completely compliant to the facet R1.1 whereas the layers failed to comply in their clear majority.

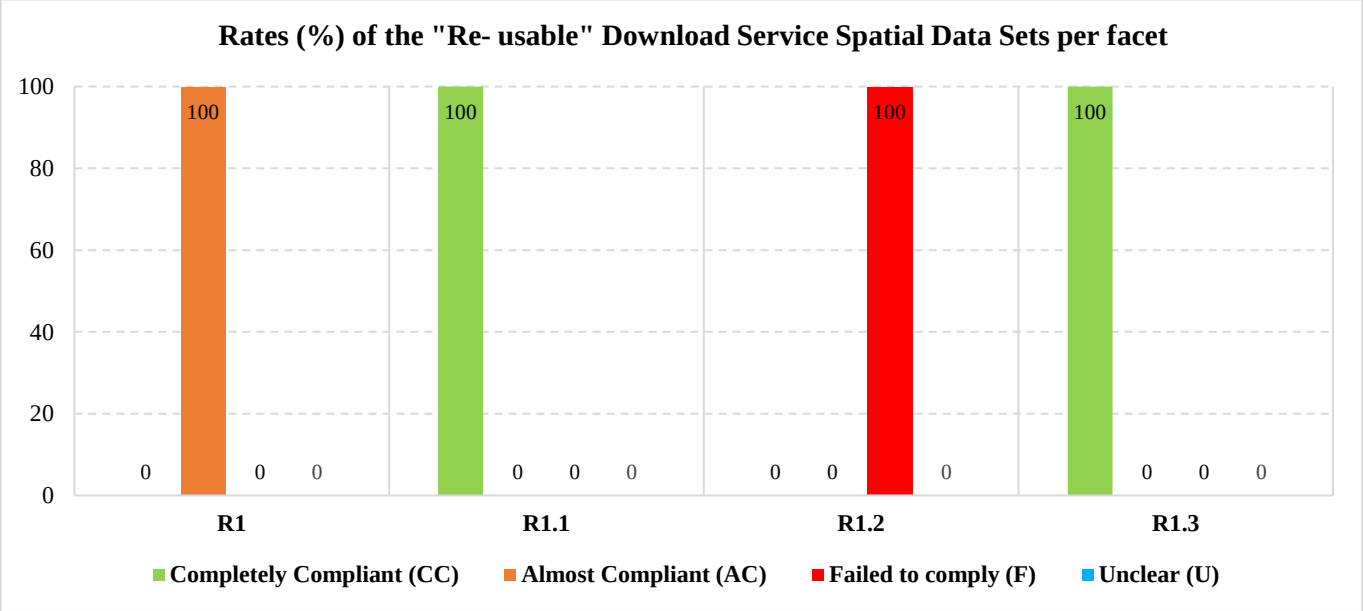

Figure 17: Rates for the "Download Service Spatial Datasets" metadata records for all the Reusability facets (R1, R1.1, R1.2 and R1.3) (see Appendix 4/Table 4-4e)

Overall, we can conclude that INSPIRE is in line with FAIR in a satisfactory level. However, the focus was on the FAIR facets for which INSPIRE failed to comply with or was vague on how it interprets the metadata. Another important point to focus on was the cases when INSPIRE was expected to be completely compliant with the FAIR facets (as presented in the theoretical evaluation) and in practice it was not rated the same. The Services and the Layers were indicative examples where INSPIRE was expected to be completely compliant for the facet F1 and in practice they both Failed to comply (with 100% and 67% respectively). The selection of the presented cases were such kind of examples where the theoretical and practical INSPIRE evaluation showed significant differences.

Chapter 4. Discussion

The objective of this research was to to ***investigate to what extent INSPIRE is ready to serve the MSFD data requirements.*** For answering this objective, three questions were formulated: 1. If INSPIRE serves in conceptual level, the MSFD data requirements, 2. If there is semantic interoperability between the INSPIRE Data Themes and the MSFD data requirements and 3. The evaluation of the results, in practice, by using the FAIR data principles. In this Chapter, the methods used, the results and possible constraints during the different research phases, are discussed per research question.

The Glossary creation

The "Glossary of MSFD terms" along with some synonyms for each term, was a critical step for having all the MSFD requirements grouped and defined. The methodology was relatively simple; all the requirements were listed and for each of them a definition was given along with one or more synonyms. GEMET was used for defining the MSFD terms and this is considered as the big advantage of this methodology. Controlled vocabularies (such as GEMET) are meant to organize information, to provide terminology, to list and retrieve information. Thus, consistency of terms is promoted and the assignment of the same terms to similar contents is achieved (Harpring, 2010; p.12) The results of RQ1, which will be discussed separately, reflecting the importance of having such a vocabulary and the lack of an MSFD controlled vocabulary simultaneously.

While trying to assign synonyms to the MSFD terms, GEMET did not support since it doesn't include any synonyms for the defined terms. Thus, other sources such as the Cambridge dictionary or a Danish MSFD related report were used. This may be considered as a disadvantage of this methodology by means of consistency between the synonym term and the scope of the MSFD requirements. The results of RQ2 reflect these potential inconsistencies and underline the need of an in- depth research for finding the synonyms that describe more accurately each MSFD term.

Research Question 1: Are the INSPIRE Data Themes able to support the MSFD on a conceptual level?

Initially, it was proved that INSPIRE can conceptually serve a large part of MSFD's data requirements. A methodology was designed to directly compare the MSFD's data requirements with the IDSs. The IDSs are very well structured and include a section in which their scope is described in detail. Moreover, there is a clear description for the reader on which spatial objects can be found under every IDS. On the contrary, MSFD's requirements are only listed in the legislation documents without being further explained. So, the reader cannot have a deep understanding of their scope. Facing the challenge of interpreting the MSFD requirements' scope, the need for a vocabulary of MSFD terms became apparent. The use of vocabularies (mainly controlled) is a common tool for policies and legislation which helps conveying their objectives. As explained, already, in the Section 2.2, by Harping et al (2010) the controlled vocabularies are beneficiary creations because they can index content in a structured way while having a defined scope or describing a specific domain. Thus, the Glossary creation became part of the methodology and already existing vocabularies or other glossaries were used as sources for definitions. A research for both the INSPIRE and the MSFD revealed that the sources of terms are either lacking in information availability or there are not available at all (mostly in case of MSFD).

If focusing on the matching attempt, the IMPP presents a similar approach of matching the MSFD requirements to one or more IDSs. The results of the IMPP resemble to the results of this research and the conclusion that INSPIRE can serve MSFD's requirements on a conceptual level can be partially validated. Partially, because the IMPP process lacks a transparent methodology on the steps followed for the matchmaking.

A limiting factor of the followed methodology was the possibility of uncovered documents. Those documents could assist for interpreting the MSFD's requirements or supporting the IMPP methodology, but they were not available or not existed at the time. Furthermore, explanations and other information regarding the scope of MSFD requirements could be hidden in the existing documents but because of their extended length the information could finally be missed or misinterpreted. Finally, multiple sources of information (such as the Cambridge Dictionary) were used for defining the MSFD terms. For approaches like the thematic matching of two Directives, where a

high level of conceptual consistency is demanded, common dictionaries or such kind may provide vague or even irrelevant information. Thus, this could be a reason for the few MSFD themes that were not matched to any IDS.

Research Question 2: Is there semantic interoperability, on attributes level, between the INSPIRE data specifications and the MSFD data requirements?

The focus of the second Research Question was on the meaning of the data, the semantics. Research has, already, been held by the IMPP on the existence of semantic interoperability between the two Directives. However, there was still a lack in a step by step methodology for evaluating the levels of semantic interoperability between the INSPIRE spatial data and the MSFD data requirements. Bishr (1998), discusses the problems occurring in data sharing, due to the existence of semantic heterogeneity between the data. He identifies two types of semantic heterogeneity: the cognitive and the naming. This research focused on the detection of naming heterogeneity for concluding on the levels of semantic interoperability. The "Glossary of terms" held a primary role in this phase. The terms were used as keywords for searching in the INSPIRE Data Specifications and finding any relevant attributes to each MSFD requirements. Since most of the MSFD requirements were successfully matched to one or more INSPIRE Data Themes, in Research Question 1, a satisfactory level of semantic interoperability was expected. INSPIRE Data Themes such as "Species Distribution", the "Bio-Geographical Regions", the "Sea Regions" etc, were among the ones that were expected to include relevant attributes since their thematic scope is in line with the marine concept of MSFD. However, the results showed high level of semantic heterogeneity, meaning low level of semantic interoperability. In their majority, IDSs were not semantically interoperable with the MSFD requirements. The high level of semantic heterogeneity could be due to the selected MSFD terms as well as their synonyms. As already discussed, the Glossary of terms was created for the purposes of this research. If analysing the defined terms, we will see that in total 119 terms were defined. More than half of these terms were defined according to different sources than GEMET. Additionally, the synonyms of all the terms were derived from sources unrelated to the GEMET or other controlled vocabularies. Consequently,

having inconsistencies between the MSFD terms and the names of INSPIRE attributes were more possible.

During the assessment of the 1st group of MSFD requirements, some INSPIRE Data Themes showed a high level of semantic heterogeneity. One case is the Elevation IDS with 50% non-semantically interoperable results; two terms were searched: the "ice" and the "bathymetry". "Ice" didn't return any relevant attribute. "Bathymetry", also, returned no results but for its synonym term "depth" spatial information were available. However, in the "Elevation" Data Specification Technical Guideline it is stated that "the theme Elevation describes digital models for describing land, ice and ocean surfaces in terms of absolute gravity-related terrestrial elevation information (heights) and bathymetry data (depths)." (D2.8. II. II_v3.0, p.1). The absence of attributes for the ice coverage lead to the assumption that ice would be either a value of an attribute and thus it is included in a code list or that detailed information about the different coverage types are not listed as attributes of a spatial object in the scope of INSPIRE. The above-mentioned case is an example of naming heterogeneity that occurred many times during this research. Finally, during the assessment of the 3rd group of MSFD requirements, there were some IDSs such as the "Protected Sites", the "Sea Regions", the "Agricultural and Aquaculture Facilities", the "Atmospheric Conditions" and the "Geology" that showed high levels of semantic heterogeneity. Again, the reason for the high levels of heterogeneity could be due to the selection of the keywords and their synonyms.

This semantic interoperability assessment between the two Directives, however, highlighted some gaps in INSPIRE application schemas. For instance, in the 1st group of requirements (see Table 2-1), which is related to the parameters and the characteristics of the ecosystem elements, 2 out of the 8 IDSs (the "Area Management/ Restriction/ Regulation Zones and Reporting Units" and the "Agriculture and Aquaculture Facilities") scored a 100% of no semantic interoperability. The "Area Management, Restriction and Regulation Zones" are zones that are established in accordance with specific legislative requirements to deliver specific environmental objectives related to every environmental media, for example, air, water, soil and biota (plants and animals)." (D2.8.III.11_v3.0, p.3) Thus, spatial information regarding the salinity or the pH of the marine waters were expected to be found. Moreover, in the "Agriculture and Aquaculture" Data Theme, information regarding the productivity of

ecosystems should be included since the “aquaculture and the marine aquaculture” are listed among “the physical instruments and constructions with permanent or semi-permanent emplacement (inland or outland) that are related to Agricultural and Aquaculture Activities (under the NACE Classification Level A -Agriculture, forestry and fishing).” (D2.8.III.9_v3.0, p.1)

Another case where INSPIRE data models should be extended is the Natural Risk Zones IDS. During the assessment of the 2nd group of MSFD requirements (See Table 2-2a), there were no relevant spatial objects or attributes regarding the extraction of wild species whereas in the informal description of the IDS it is stated that “Natural Risk Zones are zones where natural hazard areas are coincident with highly populated areas and/or areas of particular environmental, cultural, or economic value.” (D2.8.III.12_v3.0, p.1)

Another case where INSPIRE should include spatial information is the “Protected Sites”. As it is stated in the Data Specification, according to the International Union for the Conservation of Nature (IUCN) a Protected Site is an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means. (D2.8. I.9_v3.2, p.1). Consequently, any information related to restrictions in recreational or commercial fishing should be available. As it was, also, discussed in Research Question 1, there were some MSFD activities that were not matched to any IDS. Nevertheless, these requirements were assessed for their levels of semantic interoperability as all the other requirements. The result, however, showed that all of them achieved 100% of naming heterogeneity with the attributes of the INSPIRE spatial objects. Therefore, they were rated as 100% non-semantically interoperable. For example, there were no relevant INSPIRE data for forestry or for tourism and leisure (see Table 9). Since, such kind of activities can have environmental impact it is rather important that INSPIRE Data Themes should be enriched with relevant spatial information.

If we try to draw a general conclusion on whether INSPIRE can semantically support the MSFD requirements, the answer is not clear. There were many cases where an MSFD requirement was directly related to an INSPIRE spatial object whereas in most of cases there was high heterogeneity by means of names. Even in cases where the term was defined according to GEMET, there was moderate or no semantic interoperability.

In a few cases, the synonym term appeared in the attributes or in the definition/ description of a spatial object. For proceeding in semantic evaluation between two different sources of information, the keywords should be carefully selected and well defined. In this case, the "Glossary of Terms" was a first step of creating a vocabulary where the MSFD requirements would be grouped, defined and matched to one or more synonyms. However, this was an ad-hoc vocabulary that should be reviewed and revised in the future. Additionally, INSPIRE application schemas should be reviewed and possibly extended. This research revealed that for some thematic groups there were a few available spatial information while for other thematic groups such as forestry, tourism or leisure there were no relevant information available. Therefore, INSPIRE should be revised and possibly extend its application schemas and enrich them with more spatial objects and attributes.

Research Question 3: Are the data, findable, accessible, interoperable, and reusable to serve MSFD reporting?

In this Research Question, INSPIRE was evaluated both theoretically and in practice on its FAIR-ness. INSPIRE concept is concrete and in a conceptual level there are almost no gaps in the guidance it delivers to the data providers as for the publication of the data. The FAIR Data principles can be considered as an evaluation tool for the available data of a repository, a geoportal or a data source in general or a guidance tool on how the data should be made available to the public. The guidelines are clear in their demands and well-established, helping the user to understand what should be available in a dataset or a data service for being FAIR-compliant. Unquestionably, INSPIRE is a special case of SDI with a unique structure and cannot be combined with other databases or data repositories. Though, it seems that many requirements of the FAIR principles are matching the INSPIRE demands and this is a good start for future alignment between these two initiatives. It would be very useful and handy if INSPIRE could adapt with all the FAIR principles.

In the theoretical assessment INSPIRE was fully compliant with most of the FAIR facets and only a few would need to be revised. In the practical assessment, INSPIRE geoportal was evaluated based on the available marine-related data of the three IMPP countries. The number of assessed metadata records in this research was relatively low

because of: 1. the lack of an official controlled MSFD vocabulary and 2. the low availability of the marine-relevant data registered in the INSPIRE geoportal. Thus, 166 metadata records were used in the assessment.

INSPIRE metadata records were ranked as "FAIR" in a high percentage with the datasets and the series being the ones with the highest level of FAIR compliancy. There were a few cases where the facets were not in line with what INSPIRE recommends for the findability, accessibility, interoperability or reusability of data. On other cases the guidelines of the FAIR facets (i.e A2), were unclear for the INSPIRE concept. Germany has the highest number of registered metadata records among the three assessed countries followed by the Netherlands. Denmark, however, has a significantly low number of records and thus, the marine- related results were even fewer. In the Danish INSPIRE implementation reporting, it is noted that the country still faces a lot of difficulties regarding the implementation procedure. The responsible parties have not yet managed to elaborate with the concepts of INSPIRE Data modelling (i.e. the UML models). Considering the above-mentioned deficiencies together with the fact that only three EU countries were assessed any conclusion on the INSPIRE Geoportal FAIR-ness would be risky.

Overall, the metadata play a key role in the findability, accessibility, interoperability and re-usability of a dataset. The countries seem to face difficulties in implementing the legislation about INSPIRE metadata. Article 5 of INSPIRE Directive requires that "Member States shall ensure that metadata are created for the spatial data sets and services corresponding to the themes listed in Annexes I, II and III, and that those metadata are kept up to date". For instance, most of the data found in the portal (and used in the RQ3) did not include the "Spatial Data Theme" tag. There are still steps in the INSPIRE implementation roadmap that will be fulfilled in the next few years. Thus, we could expect that the countries would be facilitated and for cases such as Denmark the number of the available data may rise soon.

Lastly, it is important to note that this research cannot be conducted through data mining or other automated query searches. There should be a human to interpret the terms or a quite sophisticated AI (artificial intelligence) system.

Chapter 5. Conclusions

Research Question 1: Are the INSPIRE Data Themes able to support the MSFD on a conceptual level?

In this first research question, an effort was made to explore whether INSPIRE Data Themes can support this Directive's requirements. Since MSFD doesn't require the collection of new data for the assessment, INSPIRE was expected to include all the spatial information needed. For this theoretical assessment, the Glossary of terms was created and all the MSFD terms were used as keywords for searching through the 34 IDSs for marine- related information. The analysis revealed that more than half of the 34 IDSs were conceptually fitting to the MSFD concept. However, during this effort it was also revealed that for some of the MSFD terms there were no matching IDSs. This is an early sign for potential gaps in the INSPIRE application schemas.

Research Question 2: Is there semantic interoperability, on attributes level, between the INSPIRE data specifications and the MSFD data requirements?

In RQ1 it was proved that INSPIRE can serve the MSDF requirements in a conceptual level. However, the situation changed when it came to assess INSPIRE's and MSFD's semantic relationship. MSFD terms were used as keywords for searching in the INSPIRE UML models for relevant attributes. The assessment resulted in a high level of semantic heterogeneity between the two Directives. Almost half of the assessed MSFD terms proved to have no semantic interoperability with the INSPIRE attributes and for 20 terms there was no relevant information in the INSPIRE Data Specifications. The results reflect the need of a closer investigation on what may cause this high level of heterogeneity between these two sources of information.

Research Question 3: Are the data, findable, accessible, interoperable, and reusable to serve MSFD reporting?

INSPIRE was evaluated for its FAIR-ness both theoretically and in practice. The theoretical assessment was a comparison of what is defined in the INSPIRE legislation regarding how the data are made available and what is proposed by the FAIR principles for achieving a higher quality of available data. In this phase, INSPIRE was assessed more than a concept rather than a data repository. The analysis revealed some potential gaps in the INSPIRE implementation as for the metadata; for example, there are no

relevant information in the Technical Guidelines about whether the metadata are available in case that the data are no longer available (A2) or there is no information available in the metadata about the whom to cite in case of reusing the data (R1.2). Nevertheless, INSPIRE can be rated as compliant to the FAIR principles since it is in line with the most of the 15 FAIR facets. However, a closer investigation with the prospect of revision is suggested for the INSPIRE aspects that failed to comply or were unclear to what the FAIR guidelines propose.

For the practical evaluation, the IMPP countries (Netherlands, Germany and Denmark) were used as case countries for searching in the INSPIRE Geoportal marine-related data. The search revealed that there are very few marine-related metadata available in the INSPIRE Geoportal for these three countries. Denmark was the country with the less available marine-related metadata records. In general, this country has a significantly low number of available metadata records in the portal. Germany had the highest amount of available metadata followed by the Netherlands. Due to these differences in the number of available metadata records, the countries were not compared about their FAIR-ness. They were used as cases for narrowing down the amount of metadata records that were evaluated further. INSPIRE metadata records are available in five categories: datasets, series, layers, services (discovery, view and download) and download services spatial data sets. In this research, a total of 166 metadata records were assessed. As it is presented in the Figure 18, INSPIRE metadata records were proved to be highly **interoperable** and **re-usable** according to the FAIR principles. Their findability and accessibility were lower. The analysis showed that layers and services tended to be the less compliant in contrast to datasets and series that scored the highest compliancy rates.

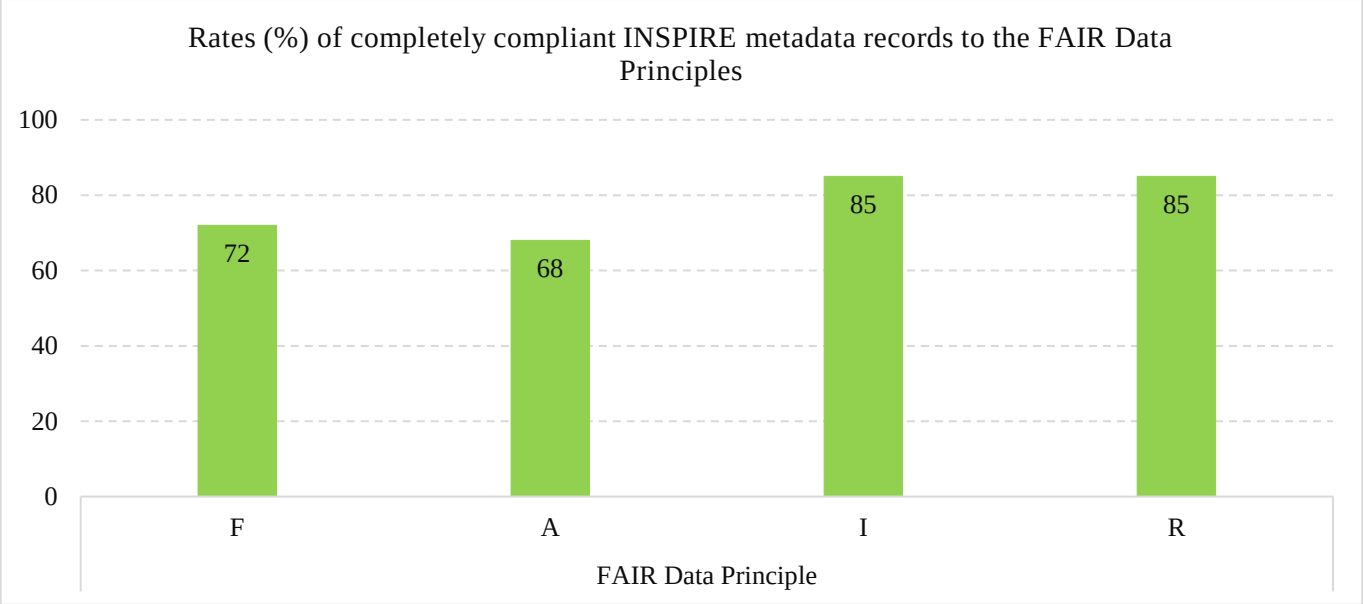

Figure 10. Rates (%) of completely compliant INSPIRE metadata records to the FAIR Data Principles.

Concluding, INSPIRE's recommendations regarding the metadata is in line with what FAIR principals propose. In practice, there are still things to be improved in order to have more metadata available and with a higher quality.

Chapter 6. Recommendations

During this research, some deficiencies were detected while assessing INSPIRE's ability to serve the MSFD data requirements. Therefore, this chapter is listing recommendations for future improvements.

For being able to proceed with the evaluation in all the stages of this research, the "Glossary of Terms" was build. As it has been stated many times, this glossary is an ad-hoc tool for facilitating the process. However, the need of building an official glossary of MSFD terms arose. For future semantic assessments, the need of a thesaurus of MSFD terms like the GEMET is critical. Thus, the keywords will be carefully selected, and the naming heterogeneity will be reduced which will result in higher levels of semantic interoperability.

While conducting the literature review, the INSPIRE website was used for finding information about the IMPP or similar use cases. However, the available input is poor regarding the implementation process, how far the case has gone, potential difficulties that are faced during the project time and so forth. Such kind of information would be very helpful for researchers that start a new topic and need to have an overview of what has been done and what needs to be investigated further. Moreover, it would be helpful if the yearly monitoring reports about INSPIRE implementation procedure in the EU MSs would be available on time. They could also be enriched with reporting of problems during the implementation or how the challenges are faced and what should be expected each year by the member state as for the data availability.

Regarding the INSPIRE geoportal, a substantial enrichment of vocabularies built behind the cross-language queries should take place. More synonyms should be added, to allow users receive more results when using a specific keyword or combination of keywords. This problem arose while searching the metadata records of the IMPP countries. Each country's metadata records are filed, in their majority, in the national language. Consequently, while searching with English keywords, results were excluded automatically. For example, when typing the English world "bathymetry" and the Dutch world "bathymetrich" in the Geoportal the results differ. It is highly recommended to attach more synonyms for achieving accuracy in the searches.

The last recommendation concerns the FAIR principles and how INSPIRE could possibly adopt them in the future. These principles are guidelines for having available data with a higher quality and consistency. They propose the mean for achieving

harmonization and interoperability. The metadata will be enriched, and the users will be provided with a plurality of details on the data producers, the origin, the purpose etc. This is a critical step for future improvements since INSPIRE pays a special attention on the data harmonization and interoperability. These are the two core elements of a well- established SDI. Europe established INSPIRE. Now INSPIRE should inspire Europe for a better data future.

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Appendix 1: Glossary for terms used in MSFD amended Annex III (OJ 125, 18.5.2017, p.30-33)

Table 1- 1: Structure, functions and processes of marine ecosystems *(OJ 125, 18.5.2017, p.30-31)*

Theme	Ecosystem element	Possible parameters and characteristics	Terms		Terms Definitions[9]	Terms Synonyms[10]
Species	Species groups of marine birds, mammals, reptiles, fish and, cephalopods of the	Spatial and temporal variation per species or population:	distribution, abundance and/or biomass	Species **Distribution**	(population distribution) The density, dispersal pattern and apportionment of the total number of persons in any area. (GEMET)	Apportionments ; allotment ; dispensation ; disposal ; dispersion ; classification ; arrangement.

[9]Sources: Technical Report from DCE –No. 16 (http://www.dmu.dk/Pub/TR16.pdf); General Multilingual Environmental Thesaurus (GEMET)
[10]Sources: http://dictionary.cambridge.org/ ; http://dictionary.sensagent.com/biomass/en-en/ ; http://www.synonym.com/synonyms/biomass

	marine region or sub region			Species **Abundance**	The relative representation of a species in a particular ecosystem or within a particular habitat. It is usually measured as the number of individuals found per area (fauna) or volume (e.g. phytoplankton) or as a combination of spatial cover and biomass (flora).	Exuberance; plenteousness; plenty; copiousness; overflow; riches; affluence; wealth; Abundance; Plenty; Exuberance
				Species **Biomass**	Biomass refers strictly speaking to the total weight of all the living things in an ecosystem. However, it has come to refer to the amount of plant and crop material that could be produced in an ecosystem for making biofuels and other raw materials used in industry, for example. (GEMET)	Mass; fuel (http://www.synonym.com/synonyms/biomass)

			size, age and sex structure	Species **Size structure**	(same as size distribution): Distribution/percentage of the total population in each size interval.	Stature; dimension; greatness; largeness; mass; proportions
				Species **Age structure**	The period of time that a person, animal or plant has lived or is expected to live. (GEMET)	become old, decline, deteriorate
				Species **sex structure**	the way in which the parts of a system or object are arranged or organized, or a system arranged in this way (Cambridge dictionary,2017)	**N/A**
			fecundity, survival and mortality/injury rates	**Fecundity**	able to produce a lot of crops, fruit, babies, young animals, etc (Cambridge dictionary,2017)	fertility, fruitfulness, productiveness
				Survival rate	1. the fact of a person, organization, etc. continuing to live or exist / 2. something that has continued to exist from a	Mean survival time; survivorship

					previous time (Cambridge dictionary,2017) / ***survival:*** The act or fact of surviving or condition of having survived. (GEMET)	
				Mortality rate (death rate)	the number of people who die in a particular group or area in a particular period of time. injure rate (Cambridge dictionary,2017)/ ***mortality:*** The number of deaths occurring in a given population for a given period of time.	death rate; fatality rate; death rate; mortality
			behaviour including movement and migration	**Behaviour**	**animal behaviour:** Behaviour of animals in their normal environment, including all the processes, both internal and external, by which they respond	Conduct; action; response

					to changes in their environment. (GEMET)	
				Movement (behaviour)	a change of position (Cambridge dictionary,2017)	Action; activity; apparent motion; apparent movement; motion; move; operation
				Migration (behaviour)	***Animal migration:*** Movements that particular animals carry out regularly often between breeding places and winter-feeding grounds. (GEMET)	Emigration; immigration
			habitat for the species (extent, suitability)	**Habitat** extent	***Animal habitat:*** The locality in which an animal naturally grows or lives. It can be either the geographical area over which it extends, or the particular station in which an animal is found. (GEMET)	abode; domicile; dwelling; environment; home; locality; natural habitat; surroundings; territory; home ground; biotope; natural habitat
				Habitat **Extent**	area or length; amount (Cambridge dictionary,2017)	Area; border; circumscription; compass;

						dimension; expanse; extension; greatness; length; region; size
				Habitat **suitability** ***(noun)***	**suitable:** acceptable or right for someone or something	Adequacy; applicability; appositeness; appropriateness; aptitude; aptness; eligibility; fitness; rightness; suitableness
			Species composition of the group	Species group **composition**	the parts, substances, etc. that something is made of	Formation; shaping; constitution
Habitats	Broad habitat types of the water column (pelagic) and seabed (benthic) (Note 5), or other habitat types, including	Per habitat type:	habitat distribution and extent (and volume, if appropriate)	**Habitat distribution**	***Distribution area:*** 1) The overall geographical distribution of a talon. 2) The range occupied by a community or other group. (GEMET)	**N/A**
				Habitat extent	*see "Habitat" and "Extend" (Theme: Species)*	*see "Habitat" and "Extend" (Theme: Species)*

	their associated biological communities throughout the marine region or sub region			**Habitat volume**	the number or amount of something in general	Amount; body; size; quantity
			species composition, abundance and/ or biomass (spatial and temporal variation)	**Species composition**	*see "Species composition" (Theme: Species)*	*see "Species composition" (Theme: Species)*
				Abundance	*see "Abundance" (Theme: Species)*	*see "Abundance" (Theme: Species)*
				Biomass	*see "Species biomass" (Theme: Species)*	*see "Species biomass" (Theme: Species)*
			size and age structure of species (if appropriate)	**Size structure of species**	*see "Species size structure" (Theme: Species)*	*see "Species size structure" (Theme: Species)*
				Age structure of species	*see "Species age structure" (Theme: Species)*	*see "Species age structure" (Theme: Species)*
			physical, hydrological	**Physical** *characteristics*	relating to things you can see or touch, or relating to the laws of nature	Natural; real

			and chemical characteristics	**Characteristics**	a typical or noticeable quality of someone or something	Features; properties; qualities; specialties; specialities
				Hydrological *characteristics* **(adjective)**	Of or pertaining to hydrology	**N/A**
				Hydrology	The science that treats the occurrence, circulation, distribution, and properties of the waters of the earth, and their reaction with the environment. (GEMET)	Related to geophysics; geophysical
				Chemical *characteristics* **(adjective)**	relating to chemicals/ Any substance used in or resulting from a reaction involving changes to atoms or molecules. (GEMET)	Alkaline; caustic; chemic
		Additionally, for pelagic habitats:	chlorophyll a concentration	**Chlorophyll** concentration	A green pigment, present in algae and higher plants, that absorbs light energy and thus	chlorophyll

					plays a vital role in photosynthesis. Except in Cyanophyta (blue-green algae), chlorophyll is confined to chloroplasts. There are several types of chlorophyll, but all contain magnesium and iron. Some plants (e.g., brown algae, red algae, copper beech trees) contain additional pigments that masks the green of their chlorophyll. (GEMET)	
			plankton bloom frequencies and spatial extend	**<u>Plankton (phytoplankton)</u>**	***Plankton:*** Small organisms (animals, plants, or microbes) passively floating in water. (GEMET)/ ***Phytoplankton*****:** Planktonic plant life. (GEMET)	**N/A**

				Spatial extend	*see "Extend" (Theme: Species)*	*see "Extend" (Theme: Species)*
Ecosystem, including food webs	Ecosystem structure, functions and processes, comprising: - physical and hydrological characteristics - chemical characteristics - biological characteristics - functions and processes	Spatial and temporal variation in:	temperature and ice	**Temperature**	A property that determines the direction of heat flow when an object is brought into thermal contact with other objects: heat flows from regions of higher to those of lower temperatures. (GEMET)	Hot; cold; warm; hotness
				Ice	The dense substance formed by the freezing of water to the solid state; it commonly occurs in the form of hexagonal crystals. (GEMET)	Frost; icing
			hydrology (wave and current regimes; upwelling,	**Wave** *regimes*	A moving ridge or swell of water occurring close to the surface of the sea, characterized by oscillating and rising and falling movements, often as a	tsunami

			mixing, residence time, freshwater input; sea level)		result of the frictional drag of the wind. (GEMET)	
				Current *regimes*	A net transport of ocean water along a definable path. (GEMET)	Stream; drift; rip; waft; (circulation)
				Upwelling	the rise of sea water from depths to the surface, typically bringing nutrients to the surface (HELCOM 2009).	**N/A**
				Mixing	Mixing of sea water occurs in response to forcing by the wind, by tides or by currents or when surface water temperature increases or decreases to the level of the deep water. Mixing often results in a surface mixed layer having homogeneous temperature and salinity. This layer may be separated from the	Admixture; amalgamation; blending; commixture; intermixture; mingling; mix; mixture

					water below it by a jump in temperature or salinity, known as a thermocline or halocline, respectively / The intermingling of different materials to produce a homogeneous mixture. (GEMET)	
				Residence time	The average amount of time a particle spends in a particular system. In an aquatic context	Duration; continuance
				Freshwater *input*	Water having a relatively low mineral content, generally less than 500 mg/l of dissolved solids. (GEMET)	Running water; surface water
				sea level	The level of the surface of the ocean; especially, the mean level halfway between high and low tide, used as a standard in	High water

					reckoning land elevation or sea depths. (GEMET)	
			bathymetry	**Bathymetry**	The study of water depth and structure of river bed or sea floor.	Water depth
			turbidity (silt/sediment loads), transparency, sound, seabed substrate and morphology	**Turbidity silt/sediment loads**	The degree to which the water loses its transparency due to the presence of suspended particulates (OSPAR 2010). / Cloudy or hazy appearance in a naturally clear liquid caused by a suspension of colloidal liquid droplets or fine solids (GEMET)	turbidness
				Transparency	the characteristic of being easy to see through (Cambridge dictionary,2017)	Transparency; cleanness; clearness; translucence; transparency; transparentness
				Sound	***sound emission:*** Diffusion into the environment of a sound	Noise emission

					emitted from a given source. (GEMET)	
				Seabed *substrate*	The bottom of the sea, including the sediment.	Sea floor; sea bottom
				Seabed **substrate**	a substance or surface that an organism grows and lives on and is supported by	ocean bottom; ocean floor; sea bottom; seafloor; sea floor
				Morphology	***Submarine morphology:*** That aspect of geological oceanography which deals with the relief features of the ocean floor and with the forces that modify them. (GEMET)	Geomorphology; sound structure; syllable structure; word structure
			salinity, nutrients (N, P), organic carbon, dissolved	**Salinity**	The mass fraction of salts in water (HELCOM 2009). / ***water salinity:*** The degree of dissolved salts in water measured by weight in parts per thousand. (GEMET)	Brininess; salt; saltiness

			gases (pCO2, O2) and pH	**Nutrients (N, P)**	A chemical element which is involved in the construction of living tissue of by both plants and animals. The most important in terms of bulk are carbon, hydrogen and oxygen, with other essential elements including nitrogen, potassium, calcium, sulphur and phosphorous (HELCOM 2009).	Feeding; nourishing; nourishment; nutriment
				Organic carbon-organic matter	Once-living material (typically with high carbon content), mostly of plant origin (HELCOM 2009). / ***organic carbon:*** Carbon which comes from an animal or plant (GEMET) ***organic matter:*** Plant and animal residue that decomposes	organic material; Natural Organic Matter; NOM

					and becomes a part of the soil. (GEMET)	
				Dissolved gases (pCO2, O2)	The partial pressure of carbon dioxide in air or liquid. The partial pressure of a gas is a measure of thermodynamic activity of the gas's molecules. Gases dissolve, diffuse, and react according to their partial pressures, and not necessarily according to their concentrations	N/A
				pH	A measure of the acidity or basicity of an aqueous solution.	N/A
			links between habitats and species of marine birds, mammals,	**Cephalopods**	Exclusively marine animals constituting the most advanced class of the Mollusca, including squid, octopuses, and Nautilus (GEMET)	cephalopod mollusc; octopus

			reptiles, fish and cephalopods	**Reptiles**	Animals characterized by laying shelled eggs (most of them), and having skin covered in scales and/or scutes. They are tetrapods (either having four limbs or being descended from four-limbed ancestors). Reptiles are classically viewed as having a" cold-blooded" metabolism. / A class of terrestrial vertebrates, characterized by the lack of hair, feathers, and mammary glands; the skin is covered with scales, they have a three-chambered heart and the pleural and peritoneal cavities are continuous (GEMET)	Animal; rattlesnake; reptilian; serpent
			pelagic-benthic	**Pelagic**	1. relating to or living in areas of the sea away from the land/ 2.	oceanic

			community structure		(of fish) living near the surface of the sea (Cambridge dictionary,2017)	
				Benthic	Adjective describing subjects or organisms associated with the substrate surface of aquatic systems – see also ‘Benthos’ / ***Benthic division:*** The bottom of a body of water often occupied by benthos. (GEMET)	Benthal; benthonic
				Benthos	Organism attached to or living on, in or near the seabed, river bed or lake floor (HELCOM 2009). / Those organisms attached to, living on, in or near the sea bed, river bed or lake floor. (GEMET)	benthic division; benthonic zone

			productivity	**Productivity**	The amount of output or yield per unit of input or expenditure achieved by a company, industry or country. (GEMET)	Efficiency; productivity; capability, effectiveness; efficacy; productiveness

Table 1-2a: Anthropogenic pressures on the marine environment matched to the ecosystem elements *(OJ 125, 18.5.2017, p.30-31)*

Theme	Pressure	Possible parameters and characteristics	Terms	Terms Definitions[11]	Terms Synonyms[12]
Biological	Input or spread of non-indigenous species	Intensity of and spatial and temporal variation in the pressure in the marine environment and, where relevant, at source. For	**Non-indigenous species**	Not indigenous; not native to an area.	Non-endemic; non autochthonous; non-native
			Microbial pathogens	of or involving or caused by or being microbes	microbic

[11]Sources: Technical Report from DCE –No. 16; http://dictionary.cambridge.org/
[12]Sources: http://dictionary.cambridge.org/ ; http://dictionary.sensagent.com/biomass/en-en/ ; http://www.synonym.com/synonyms/biomass

	Input of microbial pathogens	assessment of environmental impacts of the pressures, select relevant ecosystem elements and parameters of Table 1.	Microbial **pathogens**	***pathogen***: Any disease-producing agent or microorganism. (GEMET)	-
	Input of genetically modified species and translocation of native species		**Genetically modified species**	Definition of **GMO (abbreviation for genetically modified organism)**: a plant or animal whose genes have been scientifically changed	Genetically engineered organisms
			Translocation	a genetic abnormality (= problem) in which material from a chromosome moves to another chromosome or is exchanged with material from it	Organic process; biological process
			Native species	a person who was born in a particular place, or a **plant or animal** that lives or grows naturally in a place and has not	Homegrown; indigenous; autochthon;

				been brought from somewhere else	domestic; autochthonic
	Loss of, or change to, natural biological communities due to cultivation of animal or plant species		**Natural** community	as found in nature and not involving anything made or done by people	Physical
			Natural **community**	a group of animals or plants that live or grow together	group
			Cultivation of animal or plant **species**	production of food by preparing the land to grow crops (especially on a large scale)/ ***plant cultivation:*** The practice of growing and nurturing plants outside of their wild habitat (i.e., in gardens, nurseries, arboreta). (GEMET)	Farming; growing

	Disturbance of species (e.g. where they breed, rest and feed) due to human presence		**<u>Disturbance</u>** of species	1. something that interrupts someone or makes someone feel worried 2. cause a disturbance: to break the law by fighting or behaving extremely noisily in public	Fuss; bother; trouble
	Extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and		**<u>Wild species</u>**	**Wildlife** traditionally refers to undomesticated animal species, but has come to include all plants, fungi, and other organisms that grow or live wild in an area without being introduced by humans/ ***Wildlife***: Animals and plants that grow independently of people,	wildlife

	other activities)			usually in natural conditions. (GEMET)	
			Extraction of wild species	the process of removing something, especially by force	Removal
			Mortality of wild species	the number of deaths within a particular society and within a particular period of time	Death rate; destruction; fatality; fatality rate
			Injury of wild species	physical harm or damage to someone's body caused by an accident or an attack	Harm; trauma
			Commercial fishing	A commercial product can be bought by or is intended to be bought by the general public	Marketable; monetary
			Recreational fishing	of or relating to recreation (***recreation:*** the act of making something exist or happen again)	amateur; unpaid

Physical	Physical disturbance to seabed (temporary or reversible) (6); (7)		**Physical disturbance** to sea bed	See "***disturbance*** *of species*"	See "***disturbance*** *of species*"
	Physical loss (due to permanent change of seabed substrate or morphology and to extraction of seabed substrate)		**Physical loss** of sea bed substrate	**N/A**	**N/A**

	Changes to hydrological conditions		**Hydrological conditions**	**N/A**	**N/A**
Substances, litter and energy	Input of nutrients — diffuse sources, point sources, atmospheric deposition		**Diffuse sources**	Sources of pollution that have no specific point of discharge. Agriculture is a key source of diffuse pollution (EEA 2011)/ Pollution which arises from various activities with no discrete source. (GEMET)	**N/A**
			Point sources	Point source pollution is defined by the U.S. Environmental Protection Agency (EPA) as any single identifiable source of pollution from which pollutants are discharged, such as a pipe, ditch, ship or factory smokestack" (Hill,	Beginning sources; root sources

				1997 cited by the National Oceanic and Atmosphere Administration)	
			<u>Atmospheric deposition</u>	Deposition of nutrients, heavy metals, and other pollutants from the atmosphere (HELCOM 2009)/ ***Deposition:*** The process by which polluting material is precipitated from the atmosphere and accumulates in ecosystems.	Atmospheric impeachment; atmospheric removal
	Input of organic matter — diffuse sources and point sources		**<u>Organic matter</u>**	See "*organic carbon- organic matter*" (Theme: *Ecosystem, including food webs*)	See "*organic carbon-organic matter*" (Theme: *Ecosystem,*

					including food webs)
			<u>Diffuse sources</u>	See ***"diffuse sources"*** (Theme: Substances, litter and energy, Pressure: input of nutrients)	See ***"diffuse sources"*** (Theme: Substances, litter and energy, Pressure: input of nutrients)
	Input of other substances (e.g. synthetic substances, non-synthetic		**<u>Synthetic substances</u>**	Man-made compounds either produced intentionally or originating as side products	Man-made; unreal; artificial; semisyntheti c

	substances, radionuclides) — diffuse sources, point sources, atmospheric deposition, acute events		**Non-synthetic substances**	A compound which is of natural origin, either a chemical element or a molecule or polymer.	Natural substances
			Radionuclides	A radionuclide is an atom with an unstable nucleus, which is a nucleus characterized by excess energy which is available to be imparted either to a newly-created radiation particle within the nucleus, or else to an atomic electron. / A nuclide that exhibits radioactivity (GEMET)	Radioactive isotope; radioisotope
			Acute events	1. If a bad situation is acute, it causes severe problems or damage	Intense; sharp; critical

				2. used to describe intelligence, senses, etc. that are very good, accurate, and able to notice very small differences	
	Input of litter (solid waste matter, including micro-sized litter)		**Litter**	Straw, hay or similar material used as bedding by animals. (GEMET)	Rubbish; trash
			Solid waste	Discarded solid materials. Includes agricultural waste, mining waste, industrial waste and municipal waste. (GEMET)	Examples of waste matter: waste tires, septage, scrap metal, latex paints, furniture and toys, garbage,

					appliances and vehicles, oil and anti-freeze, empty aerosol cans, paint cans and compressed gas cylinders construction and demolition debris, asbestos (Department of

					Environmental Conservation)
			<u>Micro-sized litter</u>	See ***"Litter"***	See ***"Litter"***
	Input of anthropogenic sound (impulsive, continuous)		**<u>Anthropogenic</u>** sound	caused by humans or their activities	**N/A**
	Input of other forms of energy (including electromagnetic fields, light and heat)		**<u>Form of energy</u>**	Energy type: According to the source, energy can be classified as hydroenergy, solar energy, tidal energy, wind energy, waves energy, geothermal energy, etc. According to the type of fuel used for its production, energy can be classified as nuclear energy, coal derived energy, petroleum derived	Energy type

				energy, biomass derived energy, etc. (GEMET)	
	Input of water — point sources (e.g. brine)		**Brine**	water with salt in it, especially when used to preserve food	Drench; soak; sop

Table 1-2b: Uses and human activities in or affecting the marine environment *(OJ 125, 18.5.2017, p.30-31)*

Theme	Activity	Terms	Terms Definitions[13]	Terms Synonyms[14]
Physical restructuring of rivers, coastline or seabed (water management)	Land claim	**Land claim**	Land claim(s) are a legal declaration of desired control over areas of property including bodies of water. The phrase is usually only used with respect to disputed or unresolved land claims	**N/A**
	Canalisation and other watercourse modifications	**Canalisation**	1. management through specified channels of communication 2.the production of a canal or a conversion to canals	Channelization; channelling; channel

[13]Sources: Technical Report from DCE –No. 16; http://dictionary.cambridge.org/
[14]Sources: http://dictionary.cambridge.org/ ; http://dictionary.sensagent.com/biomass/en-en/ ; http://www.synonym.com/synonyms/biomass

		watercourse modifications	A natural stream arising in a given drainage basin but not wholly dependent for its flow on surface drainage in its immediate area, flowing in a channel with a well-defined bed between visible banks or through a definite depression in the land, having a definite and permanent or periodic supply of water, and usually, but not necessarily, having a perceptible current in a particular direction and discharging at a fixed point into another body of water. (GEMET)	Channel; aqueduct; canal; brook
	Coastal defence and flood protection	**Coastal defence**	Coastal defence (or defence) and coastal fortification are measures taken to provide protection against military attack at or near a coastline (or other shoreline), for example, fortification and coastal artillery. (Wikipedia, 2017)	**N/A**
		Flood protection	Precautionary measures, equipment or structures implemented to guard or defend people, property and lands from an unusual accumulation of water above the ground. (GEMET)	**N/A**

	Offshore structures (other than for oil/gas/renewables)	**Offshore** structures	away from or at a distance from the coast	**N/A**
	Restructuring of seabed morphology, including dredging and depositing of materials	**Seabed morphology**	See “seabed”	See “seabed”
Extraction of non-living resources	Extraction of minerals (rock, metal ores, gravel, sand, shell)	**Minerals extraction**	The process of extracting metallic or non-metallic mineral deposits from the Earth. (GEMET)	Minerals exploitation
	Extraction of oil and gas, including infrastructure	**Oil extraction**	Recovery of oil by surface mining, as in tar sands or oil shales, or from tunnels in a shallow reservoir. (GEMET)	Oil exploitation
		Gas extraction	The tapping of natural gas from wells located under the sea and in general from underground sources often in association with petroleum deposits; it is used as a fuel, having largely replaced coal-gas for this purpose, and as a source of intermediates for organic synthesis. (GEMET)	Gas exploitation
	Extraction of salt	**Salt extraction**	-	Salt exploitation

	Extraction of water	**Water extraction**	Pumping of water for different purposes (i.e. agriculture, land reclamation, domestic and industrial use, etc.). (GEMET)	Water exploitation
Production of energy	Renewable energy generation (wind, wave and tidal power), including infrastructure	**Renewable energy**	Energy derived from natural processes (e.g. sunlight and wind) that are replenished at a faster rate than they are consumed. Solar, wind, geothermal, hydro, and some forms of biomass are common sources of renewable energy. (GEMET)	Alternative energy; sustainable energy
	Non-renewable energy generation	**Non-renewable energy**	types of energy that cannot be replaced after they have been used:	**N/A**
	Transmission of electricity and communications (cables)	**Transmission of electricity**	the bulk movement of electrical energy from a generating site, such as a power plant, to an electrical substation. (Wikipedia, 2017)	Electric power transmission; electricity conveys
		Transmission of communications	In telecommunications, transmission (abbreviation: Tx) is the process of sending and propagating an analogue or digital information signal over a physical point-to-point or point-to-multipoint transmission medium, either wired, optical fibre or wireless. (Wikipedia,2017)	**N/A**

		Cables	Strands of insulated electrical conductors laid together, usually around a central core, and wrapped in a heavy insulation. (GEMET)	**N/A**
Extraction of living resources	Fish and shellfish harvesting (professional, recreational)	**Fish** (or shellfish) **harvesting**	to gather from the place where it has been growing	**N/A**
	Fish and shellfish processing	Fish (or shellfish) **processing**	The term fish processing refers to the processes associated with fish and fish products between the time fish are caught or harvested, and the time the final product is delivered to the customer (Wikipedia,2017)	**N/A**
	Marine	**plant harvesting**	Harvesting is the process of gathering a ripe crop from the fields. (Wikipedia,2017)	**N/A**
	Hunting and collecting for other purposes	**Hunting**	The pursuit and killing or capture of wild animals, regarded as a sport. (GEMET)	chasing
Cultivation of living resources	Aquaculture — marine, including infrastructure	**Marine aquaculture**	See "*Aquaculture*"	See "*Aquaculture*"
	Aquaculture — freshwater	**Freshwater**	See *"Freshwater input"*	See *"Freshwater input"*

	Agriculture	**Agriculture**	The production of plants and animals useful to man, involving soil cultivation and the breeding and management of crops and livestock. (GEMET)	**N/A**
	Forestry	**Forestry**	The management of forest lands for wood, forages, water, wildlife, and recreation. (GEMET)	**N/A**
Transport	Transport infrastructure	**Transport infrastructure**	Transport infrastructure consists of the fixed installations including roads, railways, airways, waterways, canals and pipelines and terminals such as airports, railway stations, bus stations, warehouses, trucking terminals, refuelling depots (including fuelling docks and fuel stations) and seaports.	**N/A**
	Transport — shipping	**Shipping**	Freight transport is the physical process of transporting commodities and merchandise goods and cargo. **The term shipping** originally referred to transport by sea but is extended in American English to refer to transport by land or air (International English: "carriage") as well.	Freight transport
	Transport — air	**Air transport**	The use of aircraft, predominantly airplanes, to move passengers and cargo. (GEMET)	Air transportation

	Transport — land	**Land transport**	Transport of persons and goods by a network of roads or railways. (GEMET)	land transportation
Urban and industrial uses	Urban use	**Urban use**	of or in a city or town	civic, metropolitan, municipal
	Industrial use	**Industrial use**	in or related to industry, or having a lot of industry and factories, etc	manufactured
	Waste treatment and disposal	**Waste treatment**	Any process or combination of processes that changes the chemical, physical or biological composition or character of any waste or reduces or removes its harmful properties or characteristics for any purpose. (GEMET)	**N/A**
		Waste disposal	The orderly process of discarding unwanted or useless material. (GEMET)	**N/A**
Tourism and leisure	Tourism and leisure infrastructure	**Tourism infrastructure**	Tourism infrastructure is a range of devices and institutions constituting material and organizational basis for tourism development. It comprises four basic elements: accommodation facilities, food and beverage facilities, accompanying facilities and communication facilities (Panasiuk,2007)	**N/A**

		Leisure infrastructure	Sport and leisure infrastructure encompass facilities, systems, goods and services that enable the sport and leisure (IASLIM, 2007)	**N/A**
	Tourism and leisure activities	**Tourism activities**	Tourism is defined as the activities of persons identified as visitors (The tourism society, 2017)	**N/A**
		Leisure activity	Sports and recreational activities carried out in the time free from work or other duties. (GEMET)	**N/A**
Security/defence	Military operations (subject to Article 2(2))	**Military operations**	**Military activities**: Actions and movements pertaining to or conducted by the armed forces. (GEMET)	**Military activities**
Education and research	Research, survey and educational activities	**Research** activities	Scientific investigation aimed at discovering and applying new facts, techniques and natural laws. (GEMET)	**N/A**
		survey activities	A critical examination of facts or conditions to provide information on a situation. Usually conducted by interviews and/or on-site visitations. (GEMET)	**N/A**
		educational activities	the activities of educating or instructing; activities that impart knowledge or skill	**N/A**

Appendix 2: INSPIRE Data Themes that are expected to support the MSFD data requirements

Table 2-1: Structure, functions and processes of marine ecosystems *(OJ 125, 18.5.2017, p.30-31)*

Theme	Ecosystem element	Possible parameters and characteristics		Terms used	INSPIRE Data Themes
Species	Species groups of marine birds, mammals, reptiles, fish and, cephalopods of the marine region or sub region	Spatial and temporal variation per species or population:	distribution, abundance and/or biomass	Species Distribution Species Abundance Species Biomass	Species Distribution
			size, age and sex structure	Species Size structure **Species Age structure** **Species sex structure**	Species Distribution (size structure)
			fecundity, survival and mortality/injury rates	Fecundity Survival rate	Species Distribution

				Mortality rate (death rate)	
			behaviour including movement and migration	Behaviour Movement (behaviour) Migration (behaviour)	Species Distribution
			habitat for the species (extent, suitability)	Habitat Extent Habitat Suitability *(noun)*	Species Distribution Habitats and Biotopes
			Species composition of the group	**Species composition**	**N/A**
Habitats	Broad habitat types of the water column (pelagic) and seabed (benthic) (Note 5), or other habitat types, including their associated biological communities throughout the marine region or sub region	Per habitat type:	habitat distribution and extent (and volume, if appropriate)	Habitat distribution Habitat extent Habitat volume	Species Distribution Habitats and Biotopes
			species composition, abundance and/ or	Species composition Abundance	Species Distribution

			biomass (spatial and temporal variation)	Biomass	(for the term "abundance") Bio- geographical Regions
			size and age structure of species (if appropriate)	Size structure of species Age structure of species	Species Distribution (for the term "size structure")
			physical, hydrological and chemical characteristics	Physical *characteristics* Characteristics Hydrological *characteristics* (adjective) Hydrology Chemical *characteristics* (adjective)	Sea Regions Bio-geographical Regions
		Additionally, for pelagic habitats:	chlorophyll a concentration	Chlorophyll Concentration	Bio-geographical Regions

			plankton bloom frequencies and spatial extend	Plankton (phytoplankton) Spatial extend	Sea Regions Bio-geographical Regions
Ecosystem, including food webs	Ecosystem structure, functions and processes, comprising: - physical and hydrological characteristics - chemical characteristics - biological characteristics - functions and processes	Spatial and temporal variation in:	temperature and ice	Temperature Ice	Sea Regions Bio- geographical Regions Elevation (for surfaces covered by ice) Oceanographic geographical features (for information about temperature)
			hydrology (wave and current regimes; upwelling, mixing, residence time, freshwater input; sea level)	Wave *regimes* Current *regimes* Upwelling Mixing Residence time	Sea Regions

				Freshwater input sea level	
			bathymetry	Bathymetry	Elevation Sea Regions
			turbidity (silt/sediment loads), transparency, sound seabed substrate and morphology	Turbidity silt/sediment loads Transparency Sound Seabed *substrate* Morphology	Sea Regions
			salinity, nutrients (N, P), organic carbon, dissolved gases (pCO2, O2) and pH	Salinity Nutrients (N, P) Organic carbon-organic matter Dissolved gases (pCO2, O2) pH	Sea Regions Oceanographic Geographical Features Area Management/ Restriction/Regulation Zones and Reporting Units

			links between habitats and species of marine birds, mammals, reptiles, fish and cephalopods	Cephalopods Reptiles	Species Distribution
			pelagic-benthic community structure	Pelagic community Benthic community Benthos	Species Distribution
			productivity	Productivity	Agriculture and Aquaculture Facilities

Table 2-2a: Anthropogenic pressures on the marine environment matched to the ecosystem elements *(OJ 125, 18.5.2017, p.30-31)*

Theme	Pressure	Possible parameters and characteristics	Terms used	INSPIRE Data Themes
Biological	Input or spread of non-indigenous species	Intensity of and spatial and temporal variation in the pressure in the marine environment and, where relevant, at source. For assessment of environmental impacts of the pressures, select relevant ecosystem elements and parameters of Table 1.	Non-indigenous species	Habitats and Biotopes
	Input of microbial pathogens		**Microbial pathogens**	**N/A**
	Input of genetically modified species and translocation of native species		Genetically modified species Native species	Habitats and Biotopes (for the native species)
	Loss of, or change to, natural biological communities due to cultivation of animal or plant species		Natural community Cultivation of animal or plant species	Agriculture and Aquaculture Facilities

	Disturbance of species (e.g. where they breed, rest and feed) due to human presence		Disturbance of species	Protected Sites Natural Risk Zones
	Extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities)		Wild species Extraction of wild species Mortality of wild species Injury of wild species Commercial fishing Recreational fishing	Protected Sites (includes information about sites where legislation is established for manage, regulate and restrict activities to conserve nature, biodiversity and cultural heritage only) **N**atural Risk Zones
Physical	Physical disturbance to seabed (temporary or reversible) (6); (7)		Physical disturbance to seabed	Sea Regions
	Physical loss (due to permanent change of seabed substrate or morphology and to extraction of seabed substrate)		Physical loss	Natural Risk Zones

	Changes to hydrological conditions		Hydrological conditions	Sea Regions Atmospheric Conditions and Meteorological Conditions
Substances, litter and energy	Input of nutrients — diffuse sources, point sources, atmospheric deposition		Nutrients	Atmospheric Conditions and Meteorological Conditions
	Input of organic matter — diffuse sources and point sources		**Organic matter**	**N/A**
	Input of other substances (e.g. synthetic substances, non-synthetic substances, radionuclides) — diffuse sources, point sources, atmospheric deposition, acute events		**Synthetic substances** **Non-synthetic substances** **Radionuclides** **Acute events**	**N/A**
	Input of litter (solid waste matter, including micro-sized litter)		Litter Solid waste matter Micro-sized litter	Production and Industrial Facilities
	Input of anthropogenic sound (impulsive, continuous)		Anthropogenic sound	Production and Industrial Facilities

	Input of other forms of energy (including electromagnetic fields, light and heat)		Form of energy Electromagnetic field	Energy Resources
	Input of water — point sources (e.g. brine)		Brine	Geology

Table 2-2b: Uses and human activities in or affecting the marine environment *(OJ 125, 18.5.2017, p.30-31)*

Theme	Activity	Terms used	INSPIRE Data Themes
Physical restructuring of rivers, coastline or seabed (water management)	Land claim	Land claim	Land Cover
	Canalisation and other watercourse modifications	Canalisation modifications Watercourse modifications	Utility and Government Services
	Coastal defence and flood protection	Coastal defence	Administrative Units
		Flood protection	Natural Risk Zones
	Offshore structures (other than for oil/gas/renewables)	**Offshore structures**	**N/A**
	Restructuring of seabed morphology, including dredging and depositing of materials	Seabed morphology	Sea Regions
Extraction of non-living resources	Extraction of minerals (rock, metal ores, gravel, sand, shell)	Extraction of minerals	Mineral Resources Production and Industrial Facilities
	Extraction of oil and gas, including infrastructure	Extraction of oil and gas	Energy Resources

			Production and Industrial Facilities
	Extraction of salt	Extraction of salt	Production and Industrial Facilities
	Extraction of water	Extraction of water	Production and Industrial Facilities
Production of energy	Renewable energy generation (wind, wave and tidal power), including infrastructure	Renewable energy	Energy Resources
	Non-renewable energy generation	Non-renewable energy	Utility and Government Services
	Transmission of electricity and communications (cables)	Transmission of electricity Transmission of communications	Utility and Government Services
Extraction of living resources	Fish and shellfish harvesting (professional, recreational)	Fish (or shellfish) harvesting	**NA**

	Fish and shellfish processing	Fish (or shellfish) processing	Agriculture and Aquaculture Facilities
	Marine	Plant harvesting	**N/A**
	Hunting and collecting for other purposes	Hunting	Protected Sites
Cultivation of living resources	Aquaculture — marine, including infrastructure	Aquaculture	Agriculture and Aquaculture Facilities
	Aquaculture — freshwater	Freshwater	Agriculture and Aquaculture Facilities
	Agriculture	Agriculture	Agriculture and Aquaculture Facilities
	Forestry	Forestry	**N/A**
Transport	Transport infrastructure	Transport infrastructure	Transport Network
	Transport — shipping	Shipping	Transport Network

	Transport — air	Air transport	Transport Network
	Transport — land	Land transport	Transport Network
Urban and industrial uses	Urban use	Urban	**NA**
	Industrial use	Industrial	**N/A**
	Waste treatment and disposal	Waste treatment Waste disposal	Production and Industrial Facilities Utility and Government Services
Tourism and leisure	Tourism and leisure infrastructure	Tourism infrastructure Leisure infrastructure	**N/A**
	Tourism and leisure activities	Tourism activities Leisure activities	**N/A**
Security/defence	Military operations (subject to Article 2(2))	Military operations	**N/A**
Education and research	Research, survey and educational activities	Research activities Survey activities Educational activities	Environmental Monitoring Facilities

Appendix 3: Semantic heterogeneity between the MSFD data requirements for the initial assessment of the marine waters and the spatial data of INSPIRE

Table 3-1: Structure, functions and processes of marine ecosystems (OJ 125, 18.5.2017, p.30-31)

MSFD theme	MSFD Possible parameters and characteristics	INSPIRE Data Specification	MSFD Term used for search in INSPIRE Data Theme	Case 1:	Case 2:		Case 3:	INSPIRE Spatial object with relevant attributes	Found in	Feature type or Attribute name	Level of Semantic Heterogeneity	Level of Semantic Interoperability
				MSFD Term found in feature type/ attribute name (YES/NO)	Subcase 2a: Term found in feature type/ attribute definition or description (YES/NO)	Subcase 2b: Term synonym15 found in feature type / attribute name or definition or description (Synonym/NO)	No result by using term or synonym (No result)					
Species	distribution, abundance and/or biomass	Species Distribution	Distribution	YES	-	-	-	SpeciesDistributionDataSet		-	**No** semantic heterogeneity	**High** semantic interoperability
			Abundance	NO	YES	-	-	SpeciesDistributionUnit	Feature type's **name**	DistributionInfoType	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
			Biomass	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
	size, age and sex structure	Species Distribution	Size structure	NO	YES	-	-	SpeciesDistributionUnit	-	distributionInfo	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
		N/A	**Age *structure***	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
		N/A	**sex structure**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
	fecundity, survival and mortality/injury rates	**N/A**	**Fecundity**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
		N/A	**Survival rate**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
		N/A	**Mortality rate**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
		N/A	**Death rate**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
	behaviour including movement and migration	Species Distribution	Behaviour	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability

[15] Term synonyms used in this table can be found in the Appendix 1: Glossary for MSFD amended Annex III (OJ 125, 18.5.2017, p.30-33)

			Movement (behaviour)	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Migration (behaviour)	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
		Species Distribution	Habitat	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			(Habitat) extent	YES	-	-	-	SpeciesDistributionDataSet	-	domainExtent	**No semantic heterogeneity**	**High** semantic interoperability
			(Habitat) suitability	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
		Habitats and Biotopes	Habitat	YES	-	-	-	Habitat	-	Habitat type	**No** semantic heterogeneity	**High** semantic interoperability
									Attribute's **name**	habitatSpecies	**No** semantic heterogeneity	**High** semantic interoperability
									Attribute's **name**	habitatVegetation	**No** semantic heterogeneity	**High** semantic interoperability
			Habitat extent	YES	-	-	-	HabitatDistributionDataSet	Attribute's **name**	domainExtent	**No** semantic heterogeneity	**High** semantic interoperability
				NO	NO	**Synonym:** area	-	HabitatDistributionUnit	Attribute's **name**	totalArea	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
			Habitat suitability *(noun)*	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
	Species composition of the group	**N/A**	**Species composition**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	-	**N/A**	**N/A**	**N/A**
Habitats - Per habitat type:	habitat distribution and extent (and volume, if appropriate)	Species Distribution	Habitat distribution	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Habitat extent	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Habitat volume	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
		Habitats and Biotopes	Habitat distribution	YES	-	-	-	HabitatDistributionDataSet	-	-	**No** semantic heterogeneity	**High** semantic interoperability

				YES	-	-	-	HabitatDistributionUnit	Feature type's **name**	-	**No** semantic heterogeneity	**High** semantic interoperability
			Habitat extent	NO	YES	-	-	Habitat	Feature type's **name**	geometry	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
				YES	-	-	-	HabitatDistributionDataSet	Attribute's **definition**	DomainExtent	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
			Habitat volume	YES	-	-	-	HabitatDistributionDataSet	Attribute's **name**	totalVolume	**No** semantic heterogeneity	**High** semantic interoperability
	species composition, abundance and/ or biomass (spatial and temporal variation)	Species Distribution (for the term "abundance")	Abundance	NO	YES	-	-	SpeciesDistributionUnit	Attribute's **name**	DistributionInfoType	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
		Bio- geographical Regions	Species composition	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Biomass	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Abundance	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
	size and age structure of species (if appropriate)	Species Distribution	Size structure of species	NO	YES	-	-	SpeciesDistributionUnit	-	distributionInfo	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
		N/A	**Age structure of species**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
	physical, hydrological and chemical characteristics	Sea Regions	Physical *characteristics*	NO	YES	-	-	*SeaArea*	N/A	-	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
			Hydrological *characteristics* (adjective)	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Chemical *characteristics* (adjective)	NO	YES	-	-	*SeaArea*	-	-	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
		Bio-geographical Regions	Physical *characteristics*	NO	YES	-	-	*Bio-geographicalRegion*	Feature types **definition**	-	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
			Hydrological *characteristics* (adjective)	NO	YES	-	-	*Bio-geographicalRegion*	Feature types **definition**	-	**Medium** semantic heterogeneity	**Moderate** semantic interoperability

			Hydrology	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Chemical *characteristics* (adjective)	NO	YES	-	-	*Bio-geographicalRegion*	-	-	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
Habitats- Additional for pelagic habitats :	chlorophyll a concentration	Bio-geographical Regions	Chlorophyll Concentration	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
	plankton bloom frequencies and spatial extend	Sea Regions	Plankton (phytoplankton)	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Spatial extend	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
		Bio-geographical Regions	Plankton (phytoplankton)	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			(Spatial) extent	NO	NO	area	-	*Bio-geographicalRegion*	-	-	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
Ecosystem, including food webs	temperature and ice	Sea Regions	Temperature	NO	YES	-	-	SeaArea	Feature types **definition**	parameterValue	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
			Ice	NO	YES	-	-	*MarineLayer*	Attribute's **definition**	-	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
				NO	YES	-	-	*SeaSurfaceArea*	Feature type's **definition**	-	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
		Bio- geographical Regions	Temperature	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Ice	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
		Elevation (for surfaces covered by ice)	Ice	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
		Oceanographic geographical features	Temperature	YES (in the BODC P01 Parameter Usage vocabulary)	-	-	-	-	-	-	**No** semantic heterogeneity	**High** semantic interoperability
	hydrology (wave and current regimes;	Sea Regions	Wave *regimes*	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability

	upwelling, mixing, residence time, freshwater input; sea level)		Current *regimes*	NO	NO	Circulation	-	*MarineCirculationZone*	-	-	**No semantic heterogeneity**	**High** semantic interoperability
			Upwelling	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Mixing	NO	NO	Circulation[16]	No result	*MarineCirculationZone*	-	-	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
			Residence time	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Freshwater input	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			sea level	NO	YES	-	-	*Coastline*	-	-	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
	bathymetry	Elevation	Bathymetry	NO	NO	depth	No result	*ElevationGridCoverage*	Feature type's **definition**	propertyType	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
	turbidity (silt/sediment loads), transparency, sound seabed substrate and morphology	Sea Regions	Turbidity	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Silt loads	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			sediment loads	NO	YES	-	-	MarineCirculationZone	-	zoneType	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
			Transparency	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Sound	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Seabed *substrate*	YES	-	-	-	*SeaBedArea*	-	-	**No** semantic heterogeneity	**High** semantic interoperability
			Seabed Morphology	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
		Sea Regions	Salinity	NO	YES	-	-	*MarineContour*	-	-	**Medium** semantic heterogeneity	**Moderate** semantic interoperability

[16] The *MarineCirculationZone* class should be used whenever a *SeaArea* is a marine circulation zone such as a **mixing** zone or sediment cell. (D2.8.III.16_v3.0, p.21)

	salinity, nutrients (N, P), organic carbon, dissolved gases (pCO2, O2) and pH		Nutrients (N, P)	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Organic carbon-organic matter	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Dissolved gases (pCO2, O2)	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			pH	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
		Oceanographic Geographical Features	Salinity	NO	-	-	-	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Nutrients (N, P)	YES	-	-	-	-	-	-	**No** semantic heterogeneity	**High** semantic interoperability
			Organic carbon	NO	-	-	-	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			organic matter	YES	-	-	-	-	-	-	**No** semantic heterogeneity	**High** semantic interoperability
			Dissolved gases (pCO2, O2)	YES	-	-	-	-	-	-	**No** semantic heterogeneity	**High** semantic interoperability
			pH	NO	-	-	-	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
		Area Management/ Restriction/Regulation Zones and Reporting Units	Salinity	NO	NO	NO	NO	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Nutrients (N, P)	NO	NO	NO	NO	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Organic carbon-organic matter	NO	NO	NO	NO	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Dissolved gases (pCO2, O2)	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			pH	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability

	links between habitats and species of marine birds, mammals, reptiles, fish and cephalopods	Species Distribution	Cephalopods	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Reptiles	YES	-	-	-	SpeciesDistributionUnit	-	All the attributes of this data set are relevant as they contain information about this particular dataset	**No** semantic heterogeneity	**High** semantic interoperability
	pelagic-benthic community structure	Species Distribution	Pelagic community	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Benthic community	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Benthos	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
	productivity	Agriculture and Aquaculture Facilities	Productivity	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability

Table 3-2a: Anthropogenic pressures on the marine environment matched to the ecosystem elements *(OJ 125, 18.5.2017, p.30-31)*

MSFD Theme	MSFD Pressure	INSPIRE Data Specification	MSFD Term used for search in INSPIRE Data Theme	Case1	Case 2		Case 3	INSPIRE Spatial object with relevant attributes	Found in	Feature type or Attribute name	Level of Semantic Heterogeneity	Level of Semantic Interoperability
				MSFD Term found in feature type/ attribute name (YES/NO)	Subcase 2a: Term found in feature type/ attribute definition or description (YES/NO)	Subcase 2b: Term synonym17 found in feature type / attribute name or definition or description (Synonym/NO)	No results by using term or synonym (No results)					
Biological	Input or spread of non-indigenous species	Habitats and Biotopes	Non-indigenous species	YES	-	-	-	*Habitat*	Attribute's **name**	habitatSpecies	**No** semantic heterogeneity	**High** semantic interoperability
	Input of microbial pathogens	N/A	Microbial pathogens	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Input of genetically modified species and translocation of native species	N/A	Genetically modified species	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Habitats and Biotopes	Native species	YES	-	-	-	*Habitat*	N/A	habitatSpecies	**No** semantic heterogeneity	**High** semantic interoperability
	Loss of, or change to, natural biological communities, due to cultivation of animal or plant species	Agriculture and Aquaculture Facilities	Natural community	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
			Cultivation of animal or plant species	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
	Disturbance of species (e.g. where they breed, rest and feed) due to human presence	Protected Sites	Disturbance of species	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
		Natural Risk Zones	Disturbance of species	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
	Extraction of, or mortality/injury to, wild	Protected Sites (includes	Wild species	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability

[17] Term synonyms used in this table can be found in the Appendix 1: Glossary for MSFD amended Annex III (OJ 125, 18.5.2017, p.30-33)

	species (by commercial and recreational fishing and other activities)	information about sites where legislation is established for manage, regulate and restrict activities to conserve nature, biodiversity and cultural heritage only)	Extraction of wild species	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
			Mortality of wild species	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
			Injury of wild species	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
			Commercial fishing	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
			Recreational fishing	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
		Natural Risk Zones	Wild species	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
			Extraction of wild species	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
			Mortality of wild species	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
			Injury of wild species	NO	YES	NO	-	AbstractHazardArea	Feature types **definition**	AbstractHazard Area	**Medium** semantic heterogeneity	**Moderate semantic** interoperability
			Commercial fishing	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
			Recreational fishing	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
Physical	Physical disturbance to seabed (temporary or reversible) (6); (7)	Sea Regions	Physical disturbance to seabed	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
	Physical loss (due to permanent change of seabed substrate or morphology and to extraction of seabed substrate)	Natural Risk Zones	Physical loss	NO	YES	NO	No results	AbstractHazardArea	Feature types **definition**	AbstractHazard Area	**Medium** semantic Heterogeneity	**Moderate** semantic interoperability

	Changes to hydrological conditions	Sea Regions	Hydrological conditions	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
		Atmospheric Conditions and Meteorological Conditions	Hydrological conditions	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
Substances, litter and energy	Input of nutrients — diffuse sources, point sources, atmospheric deposition	Atmospheric Conditions and Meteorological Conditions	Nutrients	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
	Input of organic matter — diffuse sources and point sources	N/A	Organic matter	N/A	N/A	N/A	N/A	N/A	-	N/A	N/A	N/A
	Input of other substances (e.g. synthetic substances, non-synthetic substances, radionuclides) — diffuse sources, point sources, atmospheric deposition, acute events	N/A	Synthetic substances	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		N/A	Non-synthetic substances	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		N/A	Radionuclides	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		N/A	Acute events	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Input of litter (solid waste matter, including micro-sized litter)	Production and Industrial Facilities	Litter	NO	NO	NO	No results	-	N/A	-	**High** semantic heterogeneity	**No** semantic interoperability
			Solid waste matter	NO	YES (waste)	NO	-	ProcessInput	-	Spatial Object Type	**Medium** semantic Heterogeneity	**Moderate** semantic interoperability
			Micro-sized litter	NO	NO	NO	No results	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
	Input of anthropogenic sound (impulsive, continuous)	Production and Industrial Facilities	Anthropogenic sound	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
	Input of other forms of energy (including electromagnetic fields, light and heat)	Energy Resources	Form of energy	NO	YES	NO	-	EnergyStatistic	-	Data Types	**Medium** semantic Heterogeneity	**Moderate** semantic interoperability
			Electromagnetic field	NO	NO	NO	No results	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability

	Input of water — point sources (e.g. brine)	Geology	Brine	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability

Table 3-2b: Uses and human activities on or affecting the marine environment *(OJ 125, 18.5.2017, p.30-31)*

MSFD Theme	MSFD Activity	INSPIRE Data Specification	MSFD Term used for search in INSPIRE Data Theme	Case1	Case 2		Case 3	INSPIRE Spatial object with relevant attributes	Found in	Feature type or Attribute name	Level of Semantic Heterogeneity	Level of Semantic Interoperability
				MSFD Term found in feature type/ attribute name (YES/NO)	Subcase 2a: Term found in feature type/ attribute definition or description (YES/NO)	Subcase 2b: Term synonym18 found in feature type / attribute name or definition or description (Synonym/NO)	No results by using term or synonym (No results)					
Physical restructuring of rivers, coastline or seabed (water management)	Land claim	Land Cover	Land claim	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
	Canalisation and other watercourse modifications	Utility and Government Services	Canalisation modifications	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
			Watercourse modifications	NO	NO	NO	No results	-	-	-	**High** semantic Heterogeneity	**No** semantic interoperability
	Coastal defence and flood protection	Administrative Units	Coastal defence	NO	YES	-	-	*MaritimeBoundary*	*Feature type's* **Description**	*MaritimeBoundary*	**Medium** semantic Heterogeneity	**Moderate** semantic interoperability
								MaritimeZone	*Feature type's* **Definition**	*MaritimeZone*	**Medium** semantic Heterogeneity	**Moderate** semantic interoperability
		Natural Risk Zones	Flood (protection)	NO	YES	-	-	*HazardArea*	*Attribute's* **Description**	magnitudeOrIntensity	**Medium** semantic Heterogeneity	**Moderate** semantic interoperability
	Offshore structures (other than for oil/gas/renewables)	**N/A**	**Offshore structures**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**

[18] Term synonyms used in this table can be found in the Appendix 1: Glossary for MSFD amended Annex III (OJ 125, 18.5.2017, p.30-33)

	Restructuring of seabed morphology, including dredging and depositing of materials	Sea Regions	Seabed morphology	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
Extraction of non-living resources	Extraction of minerals (rock, metal ores, gravel, sand, shell)	Mineral Resources	Extraction of minerals	NO	YES	-	-	*Mine*	*Feature type's* **Definition**	Mine	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
		Production and Industrial Facilities	Extraction of minerals	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
	Extraction of oil and gas, including infrastructure	Energy Resources	Extraction of oil	NO	NO	**Synonym:** exploitation	-	*VectorEnergyResource*	*Attribute's* **Description**	exploitationPeriod	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
			Extraction of gas	NO	NO	**Synonym:** exploitation	-	*VectorEnergyResource*	*Attribute's* **Description**	exploitationPeriod	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
		Production and Industrial Facilities	Extraction of oil	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
			Extraction of gas	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
	Extraction of salt	Production and Industrial Facilities	Extraction of salt	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
	Extraction of water	Production and Industrial Facilities	Extraction of water	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability
		Energy Resources	Renewable energy	NO	YES	-	-	*RenewableAndWasteResource*	*Feature type's* **Definition**	RenewableAndWasteResource	**No** semantic heterogeneity	**High** semantic interoperability
	Non-renewable energy generation	Utility and Government Services	Non-renewable energy	NO	YES	-	-	*RenewableAndWasteResource*	*Feature type's* **Description**	RenewableAndWasteResource	**No** semantic heterogeneity	**High** semantic interoperability
	Transmission of electricity and communications (cables)	Utility and Government Services	Transmission of electricity	NO	NO	**Synonym:** convey of electricity	-	*ElectricityCable*	*Feature type's* **Definition**	ElectricityCable	**Moderate** semantic heterogeneity	**Moderate** semantic interoperability
		Utility and Government Services	Transmission of communications	NO	NO	NO	No result	-	-	-	**High** semantic heterogeneity	**No** semantic interoperability

Extraction of living resources	Fish and shellfish harvesting (professional, recreational)	**N/A**	**Fish (or shellfish) harvesting**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
	Fish and shellfish processing	Agriculture and Aquaculture Facilities	Fish (or shellfish) processing	NO	YES	-	-	*AbstractInstallation*	*Feature type's* **Description**	AbstractInstallation	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
	Marine plant harvesting	**N/A**	**Plant harvesting**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
	Hunting and collecting for other purposes	Protected Sites	Hunting	NO	NO	NO	No result	-	-	-	**No** semantic heterogeneity	**High** semantic interoperability
Cultivation of living resources	Aquaculture - marine, including infrastructure	Agriculture and Aquaculture Facilities	Aquaculture	NO	YES	-	-	*Holding*	*Feature type's* **Definition**	Holding	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
	Aquaculture - freshwater	Agriculture and Aquaculture Facilities	Freshwater	NO	YES	-	-	*AquacultureInstallation*	*Attribute's* **Description**	environment	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
	Agriculture	Agriculture and Aquaculture Facilities	Agriculture	NO	YES	-	-	*AgriBuilding*	*Feature type's* **Definition & Description**	AgriBuilding	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
	Forestry	**N/A**	**Forestry**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Transport	Transport infrastructure	Transport Network	Transport infrastructure	NO	YES	-	-	*TransportNetwork*	Attribute's **Name & Definition**	typeOfTransport	**No** semantic heterogeneity	**High** semantic interoperability
	Transport — shipping	Transport Network	Shipping	NO	YES	-	-	*WaterwayLink*	*Feature type's* **Definition**	*WaterwayLink*	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
	Transport — air (SPECIAL CASE)	Transport Network	Air transport	YES	-	-	-	INSPIRE Application Schema Air Transport Network	INSPIRE Application Schema Air Transport Network	INSPIRE Application Schema Air Transport Network	**No** semantic heterogeneity	**High** semantic interoperability
	Transport — land	Transport Network	Land transport	NO	NO	NO	No result	-	-	-	**No** semantic heterogeneity	**High** semantic interoperability
Urban and industrial uses	Urban use	**N/A**	**Urban**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
	Industrial use	**N/A**	**Industrial**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
	Waste treatment and disposal	Utility and Government Services	Waste treatment	NO	YES	-	-	*EnvironmentalManagementFacility*	*Feature type's* **Definition**	EnvironmentalManagementFacility	**Medium** semantic heterogeneity	**Moderate** semantic interoperability

		Utility and Government Services	Waste disposal	NO	YES	-	-	*EnvironmentalManagementFacility*	*Feature type's* **Definition**	EnvironmentalManagementFacility	**Medium** semantic heterogeneity	**Moderate** semantic interoperability
Tourism and leisure	Tourism and leisure infrastructure	**N/A**	**Tourism infrastructure**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
		N/A	**Leisure infrastructure**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
	Tourism and leisure activities	**N/A**	**Tourism activities**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
		N/A	**Leisure activities**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Security/defence	Military operations (subject to Article 2(2))	**N/A**	**Military operations**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Education and research	Research, survey and educational activities	Environmental Monitoring Facilities	Research activities	NO	NO	NO	No result	-	-	-	**No** semantic heterogeneity	**High** semantic interoperability
			Survey activities	NO	NO	NO	No result	-	-	-	**No** semantic heterogeneity	**High** semantic interoperability
			Educational activities	NO	NO	NO	No result	-	-	-	**No** semantic heterogeneity	**High** semantic interoperability

Appendix 4: INSPIRE's FAIR-ness evaluation

Table 4: How FAIR is INSPIRE (theoretical assessment)

FAIR Data Principles		INSPIRE Regulation for Network Services (View Services, Search Services and Download Services)		Level of INSPIRE Compliancy
FINDABLE	**F1:** (meta)data are assigned a globally unique and eternally persistent identifier.	A common framework for the unique identification of spatial objects of spatial data should be established, to which identifiers under national systems can be mapped to ensure interoperability between them. (Article 8 of the DIRECTIVE 2007/2/EC)		**Complies completely**
	F2: data are described with rich metadata	INSPIRE Discovery services (see OJ L 274, 20.10.2009, p. 12) Search criteria for: - Spatial data sets and series o Keyword o Topic category o Lineage o Spatial resolution o Specification o Degree o Geographic bounding box o Conditions applying to access and use o Limitations on public access o Responsible party o Responsible party role **PLUS** o Resource Title o Resource Abstract o Resource type o Unique Resource Identifier o Temporal Reference.	- Services o Keyword o Spatial data service type o Specification o Degree o Geographic bounding box o Conditions applying to access and use o Limitations on public access o Responsible party o Responsible party role **PLUS** o Resource Title o Resource Abstract o Resource type o Temporal Reference.	**Complies completely**

	F3: (meta)data are registered or indexed in a searchable resource.	(See F2): INS NS defines as searching criteria metadata elements such as the Resource Type and the Resource Abstract.	**Complies completely**
	F4: metadata specify the data identifier.	(See F2): In INS NS it is stated that the Unique Resource Identifier is among the metadata elements that are available as searching criteria.	**Complies completely**
ACCESSIBLE	**A1:** (meta)data are retrievable by their identifier using a standardized communications protocol.	All requirements and recommendations included in the Technical Guidance for the implementation of INSPIRE Discovery Services are based on the OGC™ Catalogue Services Specification 2.0.2 - ISO Metadata Application Profile for CSW 2.0. This means that the HTTP standard is used (Technical Guidance Discovery Services v3.1, p.8)	**Complies completely**
	A1.1: the protocol is open, free, and universally implementable	All requirements and recommendations included in the Technical Guidance for the implementation of INSPIRE Discovery Services are based on the OGC™ Catalogue Services Specification 2.0.2 - ISO Metadata Application Profile for CSW 2.0	**Complies completely**
	A1.2: the protocol allows for an authentication and authorization procedure, where necessary.	For the pre-defined datasets or the pre-defined parts of the datasets the condition may be that "*The metadata contains a link (URL – uniform resource locator) whereby the dataset or part of dataset can be immediately downloaded by a simple HTTP-protocol GET-request. The URL can optionally link to a resource where rights management services can be invoked prior to the simple download by use of HTTP-protocol.*" (Technical Guidance for implementing download services using the SOS and FE Specification, p.7)	**Complies completely**
	A2: metadata are accessible, even when the data are no longer available	Relevant information not found	**Unclear**
INTEROPERABLE	**I1:** (meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation.	INSPIRE • The enumeration and code list values are uniquely identified by language-neutral mnemonic codes for computers. The values may also include a language-specific name to be used for human interaction. • The use of a common conceptual schema language (i.e. UML) allows for an automated processing of application schemas and the encoding, querying and updating of data based on the application schema – across different themes and different levels of detail. The use of UML conforms to ISO 19109 8.3 and ISO/TS 19103 with the exception that UML 2.1 instead of ISO/IEC 19501 is being used. The use of UML also conforms to ISO 19136 E.2.1.1.1-E.2.1.1.4. ISO/TS 19103 and ISO 19109 specify a profile of UML to be used in conjunction with the ISO 19100 series. This includes in particular a list of stereotypes and basic types to be used in application schemas. ISO 19136 specifies a more restricted UML profile that allows for a direct encoding in XML Schema for data transfer purposes.	**Complies completely**
	I2: (meta)data use vocabularies that follow FAIR principles.	INSPIRE recommends the use of controlled vocabularies for assigning keywords to the metadata. Also, the GEMET is suggested for selection of at least two of the total keywords used.	**Complies completely**

	I3: (meta)data include qualified references to other (meta)data.	The INSPIRE Resources Linkage Aspects express how good is the linkage among related INSPIRE resources (Spatial Data Sets metadata, View Service Layers, Download Service Spatial Data Sets). Each resource type has a specific set of aspects which help measure how well linked the resource is with a group of related resources, for example a NSDI or the whole INSPIRE Geoportal (INSPIRE Geoportal Operational Pilot_JET4) Different aspects shall apply to each metadata record type (based on INSPIRE Geoportal Operational Pilot_JET4 and TG_Metadata_ISO19139_2.0) • For datasets and data series: Unique Resource Identifier; Resource locator • For discovery services: Resource locator; *Get Discovery Service Metadata Resource* • For view services: Resource locator; Coupled Resource (links to the corresponding data set or series based on its unique resource identifier, if available) • For download services: *Get Download Service Metadata* • For layers: Unique Resource Identifier; Related resources; Resource locator	**Complies completely**
RE-USABLE	**R1:** meta(data) have a plurality of accurate and relevant attributes.	INSPIRE requires that *"Where applicable, capturing rules and associated criteria shall be specified for every spatial object type as part of a INSPIRE data specification in conformance with ISO 19131."* (D2.5_v3.4rc3.docx, p.105). However, it is still vague whether the Data Specifications are harmonized so that consistency of data is finally achieved. In Annex B of the INSPIRE GCM about the Consistency between data it is discussed that within the context of INSPIRE the consolidated model will include all INSPIRE data themes. But still, it is not sure that harmonization between the data is, finally, achieved (D2.5_v3.4rc3.docx, p. 108-109)	Almost compliant
	R1.1: (meta)data are released with a clear and accessible data usage license.	INSPIRE recommends that for detailed information about the licensing of the resource, a link to a license type (e.g. http://creativecommons.org/licenses/by/3.0), a website or to a document containing the necessary information shall be provided. (TG_Metadata_ISO19139_2.0, p27)	**Complies completely**
	R1.2: (meta)data are associated with their provenance.	It is not included in the list of metadata elements (INSPIRE should consider including this information in the future)	**Failed to comply**
	R1.3: (meta)data meet domain-relevant community standards	Analytical information about best practices for registers and registries can be found in the "Best Practices for registers and registries & Technical Guidelines for the INSPIRE register federation" document	**Complies completely**

Table 4-1i: INSPIRE marine- related metadata records for the 1st group of MSFD requirements.

Theme	Terms used	Total number of records/ terms	N of results for each case countries		
			Netherlands	Germany	Denmark
Species	Species Distribution + marine	641	2	0	0
	Species Abundance +marine	4	0	0	0
	Biomass+ marine	153	0	0	0
	Species Size	0	0	0	0
	Fecundity	8	0	0	0
	Survival rate	1	0	0	0
	Mortality rate (death rate)	0	0	0	0
	Behaviour	58	0	0	0
	Species movement (behaviour)	1	0	0	0
	Species migration (behaviour)	1	0	0	0
	Habitat Extent	88	0	0	0
	Habitat Suitability	35	0	0	0

Habitats	Habitat distribution + marine	7	0	0	0
	Habitat extent + marine	86	0	0	0
	Habitat volume + marine	0	0	0	0
	Species composition+ marine	29	0	0	0
	Abundance+ marine	6	0	0	0
	Biomass+ marine	153	0	0	0
	Species size+ marine	0	0	0	0
	Species age+ marine	3	0	0	0
	Physical *characteristics*+ marine	29	0	0	0
	Hydrological *characteristics*+ marine	1	0	0	0
	Hydrology + sea	47	0	5	0
	Chemical *characteristics*+ marine	2	0	0	0
	Chlorophyll	258	0	0	0
	Plankton	174	0	0	0
	phytoplankton	191	0	1	0
Ecosystem, including food webs	Temperature + sea	1831	30	14	0
	Ice + sea	133	0	0	0
	Wave *regime*	0	0	0	0

	Current *regime*	0	0	0	0
	Upwelling	0	0	0	0
	Mixing characteristics	0	0	0	0
	Residence time	0	0	0	0
	Freshwater input	16	0	0	0
	sea level	113	5	0	0
	Bathymetry	3215	2	4	0
	Turbidity	30	0	0	0
	Silt	181	0	0	1
	sediment loads	1	0	0	0
	Transparency + water	79	0	0	0
	Sound + water	255	0	2	0
	Seabed *substrate*	4	0	0	0
	Seabed morphology	4	0	0	0
	Salinity + water	534	0	12	0
	Nutrients (N, P)	140	0	0	0
	Organic carbon + hydro	81	0	1	0
	organic matter + water	44	0	0	0
	Dissolved gases (pCO2, O2)	1	0	0	0

	Ph	0	0	0	0
	Cephalopods	1	0	0	0
	Reptiles	112	0	4	0
	Pelagic community	1	0	0	0
	Benthic community	3	0	0	0
	Benthos	1406	1	1	0
	Productivity	17	0	0	0
Total number of metadata records		**6322**	**40**	**44**	**1**

Table 4-2a: INSPIRE marine- related metadata records for the 2nd group of MSFD requirements

Theme	Terms used	Total number of records for all MSs	N of results for each case countries		
			Netherlands	Germany	Denmark
Biological	Non-indigenous species	0	0	0	0
	Microbial pathogens	0	0	0	0
	Genetically modified species OR GMO	9	0	0	0
	Native species	34	0	0	0
	Natural community	0	0	0	0
	Cultivation of animal species	0	0	0	0
	Cultivation of plant species	0	0	0	0
	Disturbance of species	0	0	0	0
	Wild species	1	0	0	0
	Extraction of wild species	0	0	0	0

	Mortality of wild species	0	0	0	0
	Injury of wild species	0	0	0	0
	Commercial fishing	203	0	0	0
	Recreational fishing	36	0	0	0
Physical	Seabed disturbance	1	0	0	0
	Physical loss	0	0	0	0
	Hydrological conditions	0	0	0	0
Substances, litter and energy	Nutrients	140	0	0	0
	Organic matter	44	0	0	0
	Synthetic substances	0	0	0	0
	Non-synthetic substances	0	0	0	0
	Radionuclides	4	0	0	0
	Acute events	0	0	0	0
	Litter	0	0	0	0
	Solid waste matter	0	0	0	0
	Micro-sized litter	0	0	0	0

	Anthropogenic sound	0	0	0	0
	Form of energy	0	0	0	0
	Electromagnetic field	0	0	0	0
	Brine	8	0	0	0
Total number of metadata records		**480**	**0**	**0**	**0**

Table 4-2b: INSPIRE marine- related metadata records for the 3rd group of MSFD requirements

Theme	**Terms used**	**Total number of records for each term**	**N of results for each case countries**		
			Netherlands	**Germany**	**Denmark**
Physical restructuring of rivers, coastline or seabed (water management)	Land claim	5	0	0	0
	Canalisation modifications	0	0	0	0
	Watercourse modifications	0	0	0	0

	Coastal defence	0	0	0	0
	Flood protection + coast	25	0	24	0
	Offshore structures	0	0	0	0
	Seabed morphology	0	0	0	0
Extraction of non-living resources	Extraction of minerals	3	0	0	0
	Extraction of oil	0	0	0	0
	Extraction of gas	0	0	0	0
	Extraction of salt	0	0	0	0
	Extraction of water	0	0	0	0
Production of energy	Renewable energy	107	0	0	0
	Non-renewable energy	0	0	0	0
	Transmission of electricity	0	0	0	0
	Transmission of communications	0	0	0	0
Extraction of living resources	Fish (or shellfish) harvesting	0	0	0	0

	Fish (or shellfish) processing	0	0	0	0
	Plant harvesting	0	0	0	0
	Hunting	877	0	14	1
Cultivation of living resources	Aquaculture	341	23	12	1
	Freshwater	1120	0	7	0
	Agriculture + marine	141	1	0	0
	Agriculture + sea	125	0	6	0
	Forestry + marine	3	0	0	0
	Forestry + sea	14	0	0	0
	Forestry + coastal	1	0	0	0
Transport	Transport infrastructure	103	0	0	0
	Shipping	91	0	1	0
	Air transport + coastal	0	0	0	0
	Land transport	51	0	0	0
Urban and industrial uses	Urban use	0	0	0	0
	Industrial use	6	0	0	0
	Waste treatment	21	0	0	0
	Waste disposal	72	0	0	0
Tourism and leisure	Tourism infrastructure	1	0	0	0

	Leisure infrastructure	0	0	0	0
	Tourism activities	0	0	0	0
	Leisure activities	2	0	0	0
Security/defence	Military operations	0	0	0	0
Education and research	Research activities	0	0	0	0
	Survey activities	1	0	0	0
	Education + marine	11	0	0	0
Total number of Terms used	**124**				
	Total number of metadata records	**3121**	**24**	**64**	**2**

Table 4-3: How FAIR is INSPIRE Geo-portal (practical assessment)

MSFD Theme	Term used	Country	Metadata record name	Metadata record type	FINDABLE				ACCESSIBLE				INTEROPERABLE			REUSABLE			
					F1	F2	F3	F4	A1	A1.1	A1.2	A2	I1	I2	I3	R1	R1.1	R1.2	R1.3
Species	Species Distribution + marine	Netherlands	CSW Nationaal Georegister (NGR): INSPIRE-zoekdienst	Discovery service	F	CC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			INSPIRE download service PDOK	Download service	F	CC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
Habitats	Hydrology + sea	Germany	ATKIS Digitales Basis Landschaftsmodell Hamburg	Download service-Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	CC	F	CC
			Digitale Orthophotos 20cm Hamburg	Download service-Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	CC	F	CC
			Digitale Orthophotos 20cm Hamburg	Series	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Digitale Orthophotos 20cm (belaubt) Hamburg	Download service-Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	CC	F	CC
			ATKIS Digitales Basis Landschaftsmodell Hamburg	Series	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
	phytoplankton	Germany	Kartendienst Wasserrahmenrichtlinie	View Service	F	CC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
Ecosystem, including food webs	Temperature + sea	Netherlands	KNMI view service for actual synoptic observations from NL land, coastal areas and North Sea stations per 10 minutes	View Service	F	CC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Air Temperature 1 Min Average	Layer	F	AC	CC	F	F	F	F	U	CC	F	CC	AC	F	F	CC
			Station height	Layer	F	AC	CC	F	F	F	F	U	CC	F	CC	AC	F	F	CC
			Station name	Layer	F	AC	CC	F	F	F	F	U	CC	F	CC	AC	F	F	CC
			Wind Speed and direction at 10m 10 Min Average	Layer	F	AC	CC	F	F	F	F	U	CC	F	CC	AC	F	F	CC
			Air Pressure at Sea Level 1 Min Average	Layer	F	AC	CC	F	F	F	F	U	CC	F	CC	AC	F	F	CC
			Wind Direction 10 Min Average	Layer	F	AC	CC	F	F	F	F	U	CC	F	CC	AC	F	F	CC
			Wind Speed at 10m 10 Min Average	Layer	F	AC	CC	F	F	F	F	U	CC	F	CC	AC	F	F	CC
			Relative Humidity 1 Min Average	Layer	F	AC	CC	F	F	F	F	U	CC	F	CC	AC	F	F	CC
			Meteorological Optical Range 10 Min Average	Layer	F	AC	CC	F	F	F	F	U	CC	F	CC	AC	F	F	CC
			Wind Gust at 10m 10 Min Maximum	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			KNMI network of observation stations	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			KNMI actual synoptic observations from NL land, coastal areas and North Sea stations per 10 minutes	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Radiation observations	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Wind observations	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Height	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Pressure observations	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Present weather observations	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Humidity observations	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Snow depth observations	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Temperature observations	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			WMO number	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Visibility observations	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC

			Precipitation observations	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Soil Temperature observations	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Clouds observations	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Air pressure at sea level (PG)	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
		Germany	Hydrographic Data of the Mackerel and Horse Mackerel Egg Survey	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Marine Environmental Network of BSH - WMS	*Spatial data service*	F	AC	CC	F	F	F	F	U	CC	F	F	AC	CC	F	CC
			Marine Environmental Network of BSH	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	F	F	AC	CC	F	CC
			Hydrographic Data of The International Bottom Trawl Survey (1st quarter)	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Sea Surface Temperature of the North Sea and the Baltic Sea - WMS	*Spatial data service*	F	AC	CC	F	F	F	F	U	CC	F	F	AC	CC	F	CC
			Meeresoberflächentemperatur der Nord- und Ostsee - WMS	*Spatial data service*	F	AC	CC	F	F	F	F	U	CC	F	F	AC	CC	F	CC
			Hydrographic Data of the Winter Crangon Survey	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Hydrographic Data of the Soles Survey	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Hydrographic Data of German Greenland Groundfisch Survey	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Hydrographic Data of the International Bottom Trawl Survey (3rd Quarter)	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Hydrographic Data of German Autumn Survey in the Exclusive Economic Zone in the North Sea	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Hydrographic Data of the International Beam Trawl Survey	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Hydrographic Data of the German small-scale bottom trawl survey	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
	sea level	Netherlands	Air Pressure at Sea Level 1 Min Average	layer	CC	AC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Amplitude van het getij op de Noordzee Viewservice	View service	F	AC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Amplitude van het getij op de Noordzee	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Air pressure at sea level (PG)	layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Amplitude van het getij op de Noordzee Downloadservice	Download Service	F	AC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
	Bathymetry	Netherlands	Representatief Bathymetrisch Bestand	View Service	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	CC	F	CC
			EL. GridCoverage	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
		Germany	AufMod Bathymetrien aus dem funktionalen Bodenmodell 1996 - 2011	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			AufMod Bathymetrien aus dem funktionalen Bodenmodell 1996 - 2011 (Dienst)	View Service	F	AC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			AufMod Bathymetrie-Isoflächen aus dem funktionalen Bodenmodell 1996 - 2011	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			AufMod Bathymetrie-Isoflächen 1996 - 2011 für EasyGSH-DB	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
	Silt	Denmark	Indsatsområder	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
	Sound + water	Germany	Digitales Höhenmodell Hamburg DGM 1	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Digitales Höhenmodell Hamburg DGM 1	Download service-Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
	Salinity + water	Germany	Hydrographic Data of the Mackerel and Horse Mackerel Egg Survey	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Marine Environmental Network of BSH - WMS	*Spatial data service*	F	AC	CC	F	F	F	F	U	CC	CC	F	AC	CC	F	CC

			Marine Environmental Network of BSH	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Hydrographic Data of The International Bottom Trawl Survey (1st quarter)	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Hydrographic Data of a scientic cruise on the FRV 'Walther Herwig' (cruise WH287)	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Hydrographic Data of the Winter Crangon Survey	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	
			Hydrographic Data of the Soles Survey	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Hydrographic Data of German Greenland Groundfisch Survey	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Hydrographic Data of the International Bottom Trawl Survey (3rd Quarter)	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Hydrographic Data of German Autumn Survey in the Exclusive Economic Zone in the North Sea	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Hydrographic Data of the International Beam Trawl Survey	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Hydrographic Data of the German small-scale bottom trawl survey	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
	Organic carbon + hydro	Germany	Gelöster organischer Kohlenstoff (DOC)	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
	Reptiles	Germany	Artenkataster Tiere Hamburg	Spatial data set	CC	AC	CC	CC	F	F	F	U	CC	CC	F	AC	CC	F	CC
			Artendaten in Brandenburg – INSPIRE Download-Service (WFS-LFU-ARTEN)	Download Service	F	AC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Arten Brandenburg	Layer	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Artenkataster Tiere Hamburg	Download Service - Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	CC	F	CC
	Benthos	Netherlands	Kader Richtlijn Marien bevroren monitoringsdata	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
		Germany	Hydrographic Data of a scientic cruise on the FRV 'Walther Herwig' (cruise WH287)	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
Substances, litter & energy	Organic matter	Germany	Gehalte an organischer Substanz in Oberböden Deutschlands 1:1.000.000 (WMS)	View Service	F	AC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
Physical restructuring of rivers, coastline or seabed (water management)	Flood protection + coast	Germany	Ungeschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 3,00 m über NMW) in der Hansestadt Rostock	Dataset	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Ungeschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 1,00 m über NMW) in der Hansestadt Rostock	Dataset	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Hochwassergefahrenkarte „Sturmflut Ostsee“ in der Hansestadt Rostock	View service	F	CC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	F	F	CC
			Ungeschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 1,00 m über NMW) in der Hanse- und Universitätsstadt Rostock	Layer	CC	AC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Ungeschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 2,50 m über NMW) in der Hanse- und Universitätsstadt Rostock	Layer	CC	AC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Ungeschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 2,00 m über NMW) in der Hanse- und Universitätsstadt Rostock	Layer	CC	AC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Geschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 2,00 m über NMW) in der Hanse- und Universitätsstadt Rostock	Layer	CC	AC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Ungeschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 1,50 m über NMW) in der Hanse- und Universitätsstadt Rostock	Layer	CC	AC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	F	F	CC

			Ungeschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 3,00 m über NMW) in der Hanse- und Universitätsstadt Rostock	Layer	CC	AC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Geschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 1,00 m über NMW) in der Hanse- und Universitätsstadt Rostock	Layer	CC	AC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Geschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 1,50 m über NMW) in der Hanse- und Universitätsstadt Rostock	Layer	CC	AC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Hochwassergefahrenkarte „Sturmflut Ostsee“ in der Hanse- und Universitätsstadt Rostock	Layer	F	AC	CC	F	F	F	F	U	CC	F	CC	AC	F	F	CC
			Geschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 3,00 m über NMW) in der Hanse- und Universitätsstadt Rostock	Layer	CC	AC	CC	F	F	F	F	U	CC	F	CC	AC	F	F	CC
			Geschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 2,50 m über NMW) in der Hanse- und Universitätsstadt Rostock	Layer	CC	AC	CC	F	F	F	F	U	CC	F	CC	AC	F	F	CC
			Hochwassergefahrenkarte „Sturmflut Ostsee“ in der Hanse- und Universitätsstadt Rostock	View Service	F	AC	CC	F	F	F	F	U	CC	F	CC	AC	F	F	CC
			Geschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 2,00 m über NMW) in der Hansestadt Rostock	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Ungeschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 1,50 m über NMW) in der Hansestadt Rostock	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Ungeschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 2,00 m über NMW) in der Hansestadt Rostock	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Geschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 2,50 m über NMW) in der Hansestadt Rostock	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Geschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 1,00 m über NMW) in der Hansestadt Rostock	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Geschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 1,50 m über NMW) in der Hansestadt Rostock	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Geschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 3,00 m über NMW) in der Hansestadt Rostock	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Ungeschützte Gebiete der Hochwassergefahrenkarte „Sturmflut Ostsee“ (Pegel bis 2,50 m über NMW) in der Hansestadt Rostock	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
Extraction of living sources	Hunting	Germany	Jagdbezirke (Landkreis Göttingen)	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Jagdbezirke (Landkreis Göttingen)	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Jagdbezirke im Landkreis Cloppenburg	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Jagdbezirke (Landkreis Northeim)	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Hegeringe Landkreis Diepholz	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	CC	F	CC
			Hegeringe im Landkreis Rotenburg (Wümme)	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Jagdbezirke (Lkr. Osterode am Harz)	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Damwildhegegemeinschaften/ Damwildhegebezirke im Landkreis Rotenburg (Wümme)	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC

			Jagdbezirke Landkreis Lüneburg	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Jagdbezirke Landkreis Lüneburg	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Jagdbezirke im Landkreis Rotenburg (Wümme)	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Jagdbezirke im Landkreis Rotenburg (Wümme)	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Vegetationsgutachten	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Jagdbezirke Landkreis Nordwestmecklenburg	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
		Denmark	Jagtfrie områder	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Agrarische bedrijfsinformatie Nederland	Spatial data set	CC	CC	CC	CC	F	F	F	U	CC	CC	CC	AC	CC	F	CC
			Schelpdierenpercelen WMS	View Service	F	AC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			schelpdierenpercelen	Layer	CC	AC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Schelpdierenpercelen WMS	View Service	F	AC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			INSPIRE Download service voor faciliteiten voor landbouw en aquacultuur	Download Service	F	AC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Bestand Veehouderijbedrijven - Emissiepunten	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			CSW Nationaal Georegister (NGR): INSPIRE zoekdienst	Discovery Service	F	AC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Mosselzaadinvanginstallaties 2017	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Schelpdierenpercelen WFS	Download Service	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	CC	F	CC
			Bestand Veehouderijbedrijven - Bedrijven	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			INSPIRE View service voor faciliteiten voor landbouw en aquacultuur	View Service	F	AC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			BestandVeehouderijbedrijven, gebouwen	Layer	CC	AC	AC	CC	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			BestandVeehouderijbedrijven, emissiepunten	Layer	CC	AC	AC	CC	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			BestandVeehouderijbedrijven, bedrijven	Layer	CC	AC	AC	CC	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Mosselzaadinvanginstallaties WMS	View Service	F	CC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Mosselzaadinvanginstallaties 2017	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Schelpdierenpercelen 2015	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Bestand Veehouderijbedrijven - gebouwen	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			INSPIRE download service PDOK	Download Service	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
Cultivation of living resources	Aquaculture	Germany	nach BImSchG genehmigungsbedürftige Anlagen im Freistaat Sachsen	Download Service	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Bewirtschaftete Teichflächen Land Bradenburg	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Tierhaltungen im Landkreis Vorpommern-Rügen	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Tierhaltung im Freistaat Sachsen	View Service	F	CC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Ländliches Verbindungswegenetz RP	View Service	F	CC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Ländliches Verbindungswegenetz in RP	Layer	CC	AC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	CC	F	CC
			Tierhaltungsanlagen im Freistaat Sachsen	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Tierhaltung im Freistaat Sachsen	Download Service	F	CC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Fachkarte Vorranggebiete für Windenergienutzung Landkreis Diepholz	View Service	F	AC	CC	F	F	F	F	U	CC	CC	F	AC	CC	F	CC
			BImSchG- Anlagen	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	F	AC	CC	F	CC

			Biogasanlagen	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	F	AC	CC	F	CC
		Denmark	HNV indikator – High Nature Value	Spatial data set	CC	AC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
	Freshwater	Germany	Wasserschutzzonen in der Hansestadt Rostock und Umgebung	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Schwimmbäder im Saarland	Download Service - Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	CC	F	CC
			Wasserschutzzonen in der Hansestadt Rostock und Umgebung	View Service	F	CC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Wasserschutzzonen in der Hanse- und Universitätsstadt Rostock und Umgebung	Layer	CC	AC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	F	F	CC
			Schwimmbäder im Saarland	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			Wasserschutzgebiete Landkreis Rotenburg (Wümme)	Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			EIONET Messstellen Seen - Stammdaten (INSPIRE Download/ATOM)	Download Service	F	CC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
	Agriculture + marine	Netherlands	CSW Nationaal Georegister (NGR): INSPIRE zoekdienst	Discovery Service	F	CC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			INSPIRE download service PDOK	Download Service	F	CC	CC	F	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
	Agriculture + sea	Germany	ATKIS Digitales Basis Landschaftsmodell Hamburg	Download Service - Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	CC	F	CC
			Digitale Orthophotos 20cm Hamburg	Download Service - Spatial data set	CC	CC	CC	CC	CC	CC	CC	U	CC	F	CC	AC	CC	F	CC
			Digitale Orthophotos 20cm Hamburg	Spatial data set series	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
			ATKIS Digitales Basis Landschaftsmodell Hamburg	Spatial data set series	CC	CC	CC	CC	CC	CC	CC	U	CC	CC	CC	AC	CC	F	CC
Transport	Shipping	Germany	Continental Shelf Information System - Administration - WMS	Spatial data service	F	AC	CC	F	CC	CC	CC	U	CC	F	CC	AC	CC	F	CC

Tables 4-4: How FAIR is INSPIRE Geo-portal – The rating process

The following Tables are the results after analysing the records from Table 4-3 How FAIR is INSPIRE Geo-portal (practical assessment).

Tables 4-4a: DATASETS FAIR-ness

Table 4-4a1: Rates (%) of all Datasets for the "Findable" principle

Findable					
FAIR Facet/Level of compliancy	**F1 (%)**	**F2 (%)**	**F3 (%)**	**F4 (%)**	**% Findable**
Completely Compliant (CC)	100	64.4	100	100	**91.1**
Almost Compliant (AC)	0	35.6	0	0	**8.9**
Failed to comply (F)	0	0	0	0	**0**
Unclear (U)	0	0	0	0	**0**

- Number of assessed Datasets: 73
    - Number of **Completely Compliant (CC)**
        - F1= 73
        - F2= 47
        - F3= 73
        - F4= 73
    - Number of **Almost Compliant (AC)**
        - F1= 0
        - F2= 26
        - F3= 0
        - F4= 0
    - Number of **Failed to Comply (F)**
        - F1= 0
        - F2= 0
        - F3= 0
        - F4= 0

- Number of **Unclear (U)**
  - F1= 0
  - F2= 0
  - F3= 0
  - F4= 0

Table 4-4a2: Rates (%) of all Datasets for the "Accessible" principle

Accessible					
FAIR Facet/Level of compliancy	**A1 (%)**	**A1.1 (%)**	**A1.2 (%)**	**A2 (%)**	**% Accessible**
Completely Compliant (CC)	97.3	97.3	97.3	0	**72.9**
Almost Compliant (AC)	0	0	0	0	**0**
Failed to comply (F)	2.7	2.7	2.7	0	**2.1**
Unclear (U)	0	0	0	100	**25**

- Number of assessed Datasets: 73

  - Number of **Completely Compliant (CC)**
    - A1= 71
    - A1.1= 71
    - A1.2= 71
    - A2= 0

  - Number of **Almost Compliant (AC)**
    - A1= 0
    - A1.1= 0
    - A1.2= 0
    - A2= 0

  - Number of **Failed to Comply (F)**
    - A1= 2
    - A1.1= 2
    - A1.2= 2
    - A2= 0

  - Number of **Unclear (U)**
    - A1= 0
    - A1.1= 0
    - A1.2= 0

- A2= 73

Table 4-4a3: Rates (%) of all Datasets for the “Interoperable” principle

Interoperable				
FAIR Facet/Level of compliancy	**I1 (%)**	**I2 (%)**	**I3 (%)**	**% Interoperable**
Completely Compliant (CC)	100	97.3	94.5	**97.3**
Almost Compliant (AC)	0	0	0	**0**
Failed to comply (F)	0	2.7	5.5	**2.7**
Unclear (U)	0	0	0	**0**

- Number of assessed Datasets: 73
    - Number of **Completely Compliant (CC)**
        - I1= 73
        - I2= 71
        - I3= 69
    - Number of **Almost Compliant (AC)**
        - I1= 0
        - I2= 0
        - I3= 0
    - Number of **Failed to Comply (F)**
        - I1= 0
        - I2= 2
        - I3= 4
    - Number of **Unclear (U)**
        - I1= 0
        - I2= 0
        - I3= 0

Table 4-4a4: Rates (%) of all Datasets for the “Re-usable” principle

Re-usable					
FAIR Facet/Level of compliancy	**R1 (%)**	**R1.1 (%)**	**R1.2 (%)**	**R1.3 (%)**	**% Re-usable**
Completely Compliant (CC)	0	68.5	0	100.0	**42.1**
Almost Compliant (AC)	100	0	0	0	**25**
Failed to comply (F)	0	31.5	100	0	**32.9**
Unclear (U)	0	0	0	0	**0**

- Number of assessed Datasets: 73
    - Number of **Completely Compliant (CC)**
        - R1= 0
        - R1.1= 50
        - R1.2= 0
        - R1.3= 73
    - Number of **Almost Compliant (AC)**
        - R1= 73
        - R1.1= 0
        - R1.2= 0
        - R1.3= 0
    - Number of **Failed to Comply (F)**
        - R1= 0
        - R1.1= 23
        - R1.2= 73
        - R1.3= 0
    - Number of **Unclear (U)**
        - R1= 0
        - R1.1= 0
        - R1.2= 0
        - R1.3= 0

Tables 4-4b: Series

Table 4-4b1: Rates (%) of all Series for the “Findable” principle

Findable					
FAIR Facet/Level of compliancy	**F1 (%)**	**F2 (%)**	**F3 (%)**	**F4 (%)**	**% Findable**
Completely Compliant (CC)	100	100	100	100	**100**
Almost Compliant (AC)	0	0	0	0	**0**
Failed to comply (F)	0	0	0	0	**0**
Unclear (U)	0	0	0	0	**0**

- Number of assessed Series: 4
    - Number of **Completely Compliant (CC)**
        - F1= 4
        - F2= 4
        - F3= 4
        - F4= 4
    - Number of **Almost Compliant (AC)**
        - F1= 0
        - F2= 0
        - F3= 0
        - F4= 0
    - Number of **Failed to Comply (F)**
        - F1= 0
        - F2= 0
        - F3= 0
        - F4= 0
    - Number of **Unclear (U)**
        - F1= 0
        - F2= 0
        - F3= 0
        - F4= 0

Table 4-4b2: Rates (%) of all Series for the “Accessible” principle

Accessible					
FAIR Facet/Level of compliancy	**A1 (%)**	**A1.1 (%)**	**A1.2 (%)**	**A2 (%)**	**% Accessible**
Completely Compliant (CC)	100	100	100	0	**75**
Almost Compliant (AC)	0	0	0	0	**0**
Failed to comply (F)	0	0	0	0	**0**
Unclear (U)	0	0	0	100	**25**

- Number of assessed Series: 4
    - Number of **Completely Compliant (CC)**
        - A1= 4
        - A1.1= 4
        - A1.2= 4
        - A2= 0
    - Number of **Almost Compliant (AC)**
        - A1= 0
        - A1.1= 0
        - A1.2= 0
        - A2= 0
    - Number of **Failed to Comply (F)**
        - A1= 0
        - A1.1= 0
        - A1.2= 0
        - A2= 0
    - Number of **Unclear (U)**
        - A1= 0
        - A1.1= 0
        - A1.2= 0
        - A2= 4

Table 4-4b3: Rates (%) of all Series for the “Interoperable” principle

Interoperable				
FAIR Facet/Level of compliancy	**I1 (%)**	**I2 (%)**	**I3 (%)**	**% Interoperable**
Completely Compliant (CC)	100	100	100	**100**
Almost Compliant (AC)	0	0	0	**0**
Failed to comply (F)	0	0	0	**0**
Unclear (U)	0	0	0	**0**

- Number of assessed Series: 4
    - Number of **Completely Compliant (CC)**
        - I1= 4
        - I2= 4
        - I3= 4
    - Number of **Almost Compliant (AC)**
        - I1= 0
        - I2= 0
        - I3= 0
    - Number of **Failed to Comply (F)**
        - I1= 0
        - I2= 0
        - I3= 0
    - Number of **Unclear (U)**
        - I1= 0
        - I2= 0
        - I3= 0

Table 4-4b4: Rates (%) of all Series for the “Re-usable” principle

Re-usable					
FAIR Facet/Level of compliancy	**R1 (%)**	**R1.1 (%)**	**R1.2 (%)**	**R1.3 (%)**	**% Re-usable**
Completely Compliant (CC)	0	100	0	100	**50**
Almost Compliant (AC)	100	0	0	0	**25**
Failed to comply (F)	0	0	100	0	**25**
Unclear (U)	0	0	0	0	**0**

- Number of assessed Series: 4
    - Number of **Completely Compliant (CC)**
        - R1= 0
        - R1.1= 4
        - R1.2= 0
        - R1.3= 4
    - Number of **Almost Compliant (AC)**
        - R1= 4
        - R1.1= 0
        - R1.2= 0
        - R1.3= 0
    - Number of **Failed to Comply (F)**
        - R1= 0
        - R1.1= 0
        - R1.2= 4
        - R1.3= 0
    - Number of **Unclear (U)**
        - R1= 0
        - R1.1= 0
        - R1.2= 0
        - R1.3= 0

Tables 4-4c: Services

Table 4-4c1: Rates (%) of all Services for the "Findable" principle

Findable					
FAIR Facet/Level of compliancy	**F1 (%)**	**F2 (%)**	**F3 (%)**	**F4 (%)**	**% Findable**
Completely Compliant (CC)	0	42.9	100	0	35.7
Almost Compliant (AC)	0	57.1	0	0	14.3
Failed to comply (F)	100	0	0	100	50
Unclear (U)	0	0	0	0	0

- Number of assessed Services: 35
    - Number of **Completely Compliant (CC)**
        - F1= 0
        - F2= 15
        - F3= 35
        - F4= 0
    - Number of **Almost Compliant (AC)**
        - F1= 0
        - F2= 20
        - F3= 0
        - F4= 0
    - Number of **Failed to Comply (F)**
        - F1= 35
        - F2= 0
        - F3= 0
        - F4= 35
    - Number of **Unclear (U)**
        - F1= 0
        - F2= 0
        - F3= 0
        - F4= 0

Table 4-4c2: Rates (%) of all Services for the “Accessible” principle

Accessible					
FAIR Facet/Level of compliancy	**A1 (%)**	**A1.1 (%)**	**A1.2 (%)**	**A2 (%)**	**% Accessible**
Completely Compliant (CC)	80	82.9	82.9	0	61.4
Almost Compliant (AC)	0	0	0	0	0
Failed to comply (F)	20	17.1	17.1	0	13.6
Unclear (U)	0	0	0	100	25

- Number of assessed Services: 35
    - Number of **Completely Compliant (CC)**
        - A1= 28
        - A1.1= 29
        - A1.2= 29
        - A2= 0
    - Number of **Almost Compliant (AC)**
        - A1= 0
        - A1.1= 0
        - A1.2= 0
        - A2= 0
    - Number of **Failed to Comply (F)**
        - A1= 7
        - A1.1= 6
        - A1.2= 6
        - A2= 0
    - Number of **Unclear (U)**
        - A1= 0
        - A1.1= 0
        - A1.2= 0
        - A2= 35

Table 4-4c3: Rates (%) of all Services for the “Interoperable” principle

Interoperable				
FAIR Facet/Level of compliancy	**I1 (%)**	**I2 (%)**	**I3 (%)**	**% Interoperable**
Completely Compliant (CC)	100	80	85.7	**88.6**
Almost Compliant (AC)	0	0	0	**0**
Failed to comply (F)	0	20	14.3	**11.4**
Unclear (U)	0	0	0	**0**

- Number of assessed Services: 35
    - Number of **Completely Compliant (CC)**
        - I1= 35
        - I2= 28
        - I3= 30
    - Number of **Almost Compliant (AC)**
        - I1= 0
        - I2= 0
        - I3= 0
    - Number of **Failed to Comply (F)**
        - I1= 0
        - I2= 7
        - I3= 5
    - Number of **Unclear (U)**
        - I1= 0
        - I2= 0
        - I3= 0

Table 4-4c4: Rates (%) of all Services for the “Re-usable” principle

Re-usable					
FAIR Facet/Level of compliancy	**R1 (%)**	**R1.1 (%)**	**R1.2 (%)**	**R1.3 (%)**	**% Re-usable**
Completely Compliant (CC)	0	94.3	0	100	**48.6**
Almost Compliant (AC)	100	0	0	0	**25**
Failed to comply (F)	0	5.7	100	0	**26.4**
Unclear (U)	0	0	0	0	**0**

- Number of assessed Services: 35
    - Number of **Completely Compliant (CC)**
        - R1= 0
        - R1.1= 33
        - R1.2= 0
        - R1.3= 35
    - Number of **Almost Compliant (AC)**
        - R1= 35
        - R1.1= 0
        - R1.2= 0
        - R1.3= 0
    - Number of **Failed to Comply (F)**
        - R1= 0
        - R1.1= 2
        - R1.2= 35
        - R1.3= 0
    - Number of **Unclear (U)**
        - R1= 0
        - R1.1= 0
        - R1.2= 0
        - R1.3= 0

Tables 4-4d: Layers

Table 4-4d1: Rates (%) of all Layers for the "Findable" principle

Findable					
FAIR Facet/Level of compliancy	**F1 (%)**	**F2 (%)**	**F3 (%)**	**F4 (%)**	**% Findable**
Completely Compliant (CC)	37	0	93.5	32.6	40.8
Almost Compliant (AC)	0	100	6.5	0	26.6
Failed to comply (F)	63	0	0	67.4	32.6
Unclear (U)	0	0	0	0	0

- Number of assessed Layers: 46
    - Number of **Completely Compliant (CC)**
        - F1= 17
        - F2= 0
        - F3= 43
        - F4= 15
    - Number of **Almost Compliant (AC)**
        - F1= 0
        - F2= 46
        - F3= 3
        - F4= 0
    - Number of **Failed to Comply (F)**
        - F1= 29
        - F2= 0
        - F3= 0
        - F4= 31
    - Number of **Unclear (U)**
        - F1= 0
        - F2= 0
        - F3= 0
        - F4= 0

Table 4-4d2: Rates (%) of all Layers for the “Accessible” principle

Accessible					
FAIR Facet/Level of compliancy	**A1 (%)**	**A1.1 (%)**	**A1.2 (%)**	**A2 (%)**	**% Accessible**
Completely Compliant (CC)	73.9	73.9	73.9	0	55.4
Almost Compliant (AC)	0	0	0	0	0
Failed to comply (F)	26.1	26.1	26.1	0	20
Unclear (U)	0	0	0	100	25

- Number of assessed Layers: 46
    - Number of **Completely Compliant (CC)**
        - A1= 34
        - A1.1= 34
        - A1.2= 34
        - A2= 0
    - Number of **Almost Compliant (AC)**
        - A1= 0
        - A1.1= 0
        - A1.2= 0
        - A2= 0
    - Number of **Failed to Comply (F)**
        - A1= 12
        - A1.1= 12
        - A1.2= 12
        - A2= 0
    - Number of **Unclear (U)**
        - A1= 0
        - A1.1= 0
        - A1.2= 0
        - A2= 0

Table 4-4d3: Rates (%) of all Layers for the “Interoperable” principle

Interoperable				
FAIR Facet/Level of compliancy	**I1 (%)**	**I2 (%)**	**I3 (%)**	**% Interoperable**
Completely Compliant (CC)	100	0	100	67
Almost Compliant (AC)	0	0	0	0
Failed to comply (F)	0	100	0	33
Unclear (U)	0	0	0	0

- Number of assessed Layers: 46
    - Number of **Completely Compliant (CC)**
        - I1= 46
        - I2= 0
        - I3= 46
    - Number of **Almost Compliant (AC)**
        - I1= 0
        - I2= 0
        - I3= 0
    - Number of **Failed to Comply (F)**
        - I1= 0
        - I2= 46
        - I3= 0
    - Number of **Unclear (U)**
        - I1= 0
        - I2= 0
        - I3= 0

Table 4-4d4: Rates (%) of all Layers for the “Re-usable” principle

Re-usable					
FAIR Facet/Level of compliancy	**R1 (%)**	**R1.1 (%)**	**R1.2 (%)**	**R1.3 (%)**	**% Re-usable**
Completely Compliant (CC)	0	2.2	0	100	25.5
Almost Compliant (AC)	100	0	0	0	25.0
Failed to comply (F)	0	97.8	100	0	49.5
Unclear (U)	0	0	0	0	0.0

- Number of assessed Layers: 46
    - Number of **Completely Compliant (CC)**
        - R1= 0
        - R1.1= 1
        - R1.2= 0
        - R1.3= 46
    - Number of **Almost Compliant (AC)**
        - R1= 46
        - R1.1= 0
        - R1.2= 0
        - R1.3= 0
    - Number of **Failed to Comply (F)**
        - R1= 0
        - R1.1= 45
        - R1.2= 46
        - R1.3= 0
    - Number of **Unclear (U)**
        - R1= 0
        - R1.1= 0
        - R1.2= 0
        - R1.3= 0

Table 4-4e: Download Service Spatial Data Sets

Table 4-4e1: Rates (%) of all Download Service Spatial Datasets for the “Findable” principle

Findable					
FAIR Facet/Level of compliancy	**F1 (%)**	**F2 (%)**	**F3 (%)**	**F4 (%)**	**% Findable**
Completely Compliant (CC)	100	75	100	100	94
Almost Compliant (AC)	0	25	0	0	6
Failed to comply (F)	0	0	0	0	0
Unclear (U)	0	0	0	0	0

- Number of assessed Download Service Spatial Data Sets: 8
    - Number of **Completely Compliant (CC)**
        - F1= 8
        - F2= 6
        - F3= 8
        - F4= 8
    - Number of **Almost Compliant (AC)**
        - F1= 0
        - F2= 2
        - F3= 0
        - F4= 0
    - Number of **Failed to Comply (F)**
        - F1= 0
        - F2= 0
        - F3= 0
        - F4= 0
    - Number of **Unclear (U)**
        - F1= 0
        - F2= 0
        - F3= 0
        - F4= 0

Table 4-4e2: Rates (%) of all Download Service Spatial Datasets for the “Accessible” principle

Accessible					
FAIR Facet/Level of compliancy	**A1 (%)**	**A1.1 (%)**	**A1.2 (%)**	**A2 (%)**	**% Accessible**
Completely Compliant (CC)	100	100	100	0	75
Almost Compliant (AC)	0	0	0	0	0
Failed to comply (F)	0	0	0	0	0
Unclear (U)	0	0	0	100	25

- Number of assessed Download Service Spatial Data Sets: 8
  - Number of **Completely Compliant (CC)**
    - A1= 8
    - A1.1= 8
    - A1.2= 8
    - A2= 0
  - Number of **Almost Compliant (AC)**
    - A1= 0
    - A1.1= 0
    - A1.2= 0
    - A2= 0
  - Number of **Failed to Comply (F)**
    - A1= 0
    - A1.1= 0
    - A1.2= 0
    - A2= 0
  - Number of **Unclear (U)**
    - A1= 0
    - A1.1= 0
    - A1.2= 0
    - A2= 8

Table 4-4e3: Rates (%) of all Download Service Spatial Datasets for the “Interoperable” principle

Interoperable				
FAIR Facet/Level of compliancy	**I1 (%)**	**I2 (%)**	**I3 (%)**	**% Interoperable**
Completely Compliant (CC)	100	12.5	100	70.8
Almost Compliant (AC)	0	0	0	0
Failed to comply (F)	0	87.5	0	29.2
Unclear (U)	0	0	0	0

- Number of assessed Download Service Spatial Data Sets: 8
    - Number of **Completely Compliant (CC)**
        - I1= 8
        - I2= 1
        - I3= 8
    - Number of **Almost Compliant (AC)**
        - I1= 0
        - I2= 0
        - I3= 0
    - Number of **Failed to Comply (F)**
        - I1= 0
        - I2= 7
        - I3= 0
    - Number of **Unclear (U)**
        - I1= 0
        - I2= 0
        - I3= 0

Table 4-4e4: Rates (%) of all Download Service Spatial Datasets for the “Re-usable” principle

Re-usable					
FAIR Facet/Level of compliancy	**R1 (%)**	**R1.1 (%)**	**R1.2 (%)**	**R1.3 (%)**	**% Re-usable**
Completely Compliant (CC)	0	100	0	100	50
Almost Compliant (AC)	100	0	0	0	25
Failed to comply (F)	0	0	100	0	25
Unclear (U)	0	0	0	0	0

- Number of assessed Download Service Spatial Data Sets: 8
  - Number of **Completely Compliant (CC)**
    - R1= 0
    - R1.1= 8
    - R1.2= 0
    - R1.3= 8
  - Number of **Almost Compliant (AC)**
    - R1= 8
    - R1.1= 0
    - R1.2= 0
    - R1.3= 0
  - Number of **Failed to Comply (F)**
    - R1= 0
    - R1.1= 0
    - R1.2= 8
    - R1.3= 0
  - Number of **Unclear (U)**
    - R1= 0
    - R1.1= 0
    - R1.2= 0
    - R1.3= 0