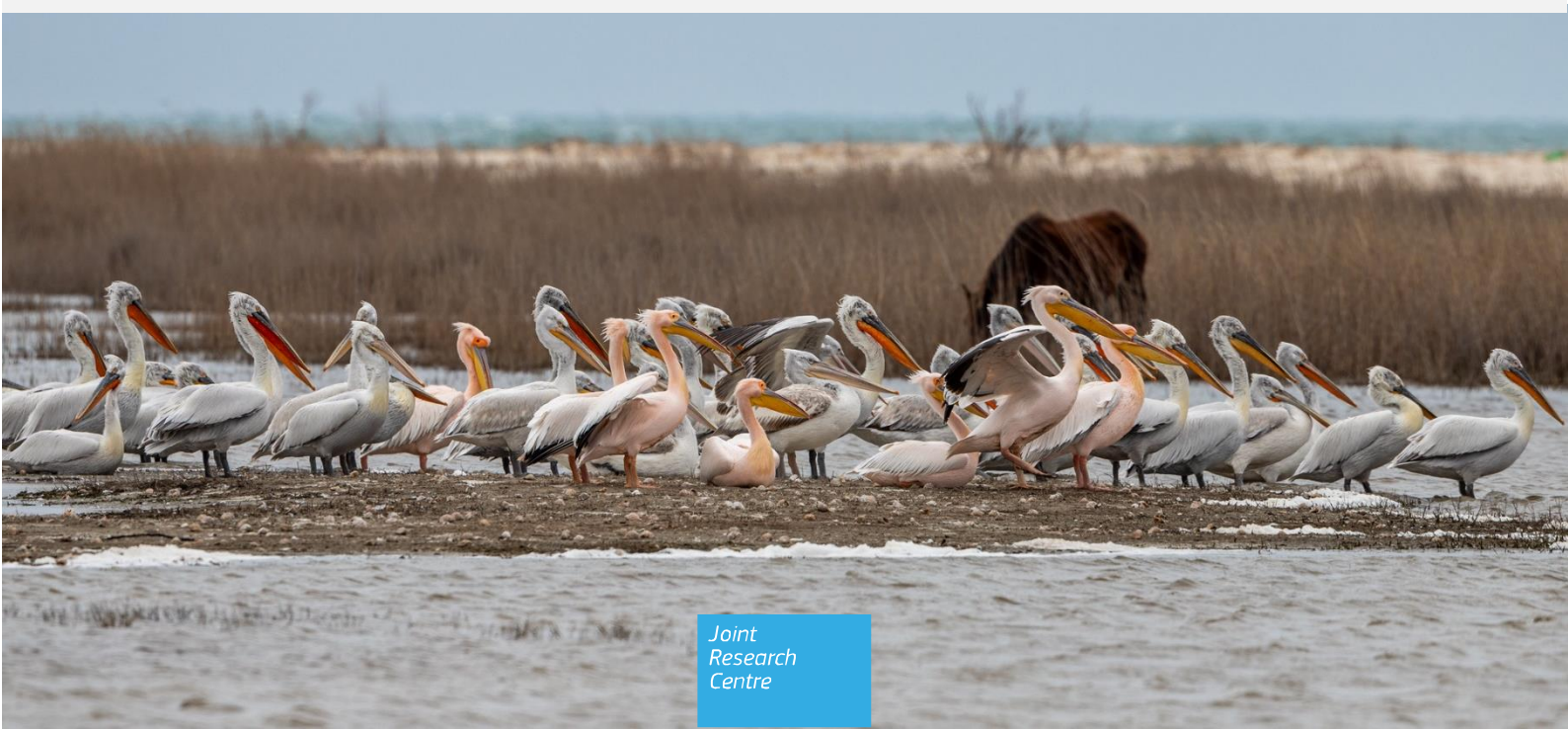
European Commission

Review of key biodiversity data in Europe

Kefalas, G., Lorilla, R.S., Bormpoudakis, D., Drakou, E.G.

2025



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Contents

Abstract

The effectiveness of management and conservation actions relies, among others, on the availability of biodiversity data. For these data to be effectively utilized, their accuracy, completeness, and accessibility are prerequisites and thus various datasets focusing on different aspects and levels of ecosystems have been developed and launched over the years. In this context, the aim of this report is to provide a critical analysis of the biodiversity datasets in Europe. To achieve this, opportunistic and targeted searching procedures were followed, using data's geographical nature, accessibility, and coverage as criteria. Hence, 29 data repositories were assessed, from which 102 datasets were selected and further evaluated. 62 datasets were species-specific, 33 were habitat-specific, 3 were species' habitat specific, and 4 datasets referred to biodiversity indices. In terms of taxa, the most representative classes (by number of data retrieved) were vascular plants, followed by mammals and birds, while in terms of realms, marine ecosystems were more represented than terrestrial ecosystems. Regarding spatial completeness, the northern, western, and central regions of Europe had more available data compared to the eastern and southern regions. However, for species and habitats that fall under the framework of European directives, data were available for the entire European territory and seas. Thus, the current report provides useful insights into the available biodiversity data, which can be used for research purposes and to promote current and future European policies and actions, especially those related with environmental data accessibility.

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1 Introduction

Biodiversity, the variety of life on Earth, plays a fundamental role in maintaining the balance and functioning of ecosystems. Still to now, the ongoing attempts by policy and conservation efforts towards safeguarding biodiversity have been failing (Mace et al., 2010). To effectively conserve and manage biodiversity, it is essential – among others - to document and monitor its spatial distribution (Nemec & Raudsepp-Hearne, 2013). Biodiversity knowledge continues to be enhanced as the amount and accuracy of the acquired data on species and habitats increase due to the integration of novel technologies and earth observation techniques in monitoring processes (Hobern et al., 2013). Biodiversity geodatabases serve as valuable repositories of geospatial data, allowing us to analyze patterns, identify hotspots, and help make informed decisions regarding conservation and development efforts towards more sustainable futures (Feng et al., 2022). With the Restoration Law of the EU coming into force since August 2024 and considering the new EU Green Deal which targets Sustainable Development, knowing which biodiversity datasets can be used to provide the most accurate information, their level of completeness and the information they can provide decision-makers with, is critical. Highlighting their strong points and their knowledge gaps, is essential to guide future biodiversity data collection and coordination efforts, but also to guide decisions on where development can happen with a minimum harm for biodiversity, or where restoration and conservation efforts should focus (Feng et al., 2022).

Over the years, several attempts have been made to assess the completeness and quality of biodiversity data, either at a global level (Feng et al., 2022; Moussy et al., 2022) or regionally (Oliveira et al., 2016; Stropp et al., 2016; Wetzel et al., 2018). These studies have identified data gaps, limitations, and inaccuracies, while also suggesting actions to improve data accuracy, transparency, and accessibility. Considering the critical knowledge gaps for scientists and the ineffectiveness of working with incomplete and often unrepresentative data, Hortal et al. (2015) identified seven crucial shortfalls in biodiversity knowledge. Two of these, namely Wallacean and Prestonian shorfalls, are highly relevant to the limitations highlighted by the global and regional studies. Specifically, the Wallacean shortfall focuses on the spatial aspect of the data and recognizes that spatial information for most species is incomplete or, in cases where it exists, the scale of analysis is inappropriate. The Prestonian shortfall introduces the time dimension, pointing out that data on species dynamics often lack information about time and space. Such conclusions are in line with other studies, which recognize that despite the increase in the number of monitored species over the years, many taxonomic groups or certain species are misrepresented. Globally, Moussy et al. (2022) reported that invertebrates, molluscs, crustaceans, and other taxa are poorly monitored compared to certain vertebrates (such as birds and mammals) and plants. Wetzel et al. (2018) assessed biodiversity data in Europe acquired from nine widely used providers, including GBIF, OBIS, ERMS, and others. One of the main findings was that although Europe is rich in biodiversity data, the available data for several taxonomic groups, including reptiles and mammals, are limited. Similarly, certain shortfalls can also be found in taxa-oriented data repositories. For instance, Stropp et al. (2016), by analyzing over 3.5 million records of flowering plants, found that only 30% of those records do not contain erroneous or incomplete information, and only 1% are relatively well sampled. Sampling is an important aspect of data acquisition with a critical impact on the accuracy and completeness of the data provided. Therefore, aiming to evaluate the effect of sampling bias on biodiversity information, Oliveira et al. (2016) analyzed 1.5 million records of arthropods, vertebrates, and angiosperms in Brazil proved that knowledge of the distribution patterns of biodiversity is highly influenced by the sampling strategy.

Understanding the core limitations of data repositories, two main pathways are suggested. The first pathway focuses solely on the quality of the data, proposing that data should be critically assessed

prior to their integration into a repository or before being used (Stropp et al., 2016). The second pathway emphasizes the availability and distribution of the data, recommending the establishment of a centralized and freely accessible repository (Feng et al., 2022; Moussy et al., 2022). In this framework, Hobern et al. (2013) and Wetzel et al. (2018) suggested the fundamentals of this repository, where data accessibility and discoverability should be at the core of this initiative. Specifically, they indicated that the main observed gaps in biodiversity data might be the result of inaccessibility or poor labelling of a large amount of data. Therefore, by developing a common biodiversity database in which data is appropriately stored under strict protocols, such limitations could be overcome. In parallel, as data is distributed via various sources hosted by different agencies, institutions, or programs, searching for and acquiring desired data can be a difficult task, which is often not completed successfully.

In this context, **the aim of this report is to provide a critical analysis of the biodiversity data repositories that cover Europe**, including (but not restricted to) the global and the European Red Lists, datasets from large organizations and datasets from global, EU-wide and regional initiatives. We define as data repositories any kind of geodatadases or/and inventories in which biodiversity datasets covering any level of biodiversity. Within the explored biodiversity data repositories, datasets with georeferenced biodiversity information in Europe, were explored in detail to assess their completeness in terms of geographical coverage, the type and level of information they provide on species distributions and their habitats, as well as attributes related to their resolution and accessibility.

This work has been used to explore European repositories and potentially update the Digital Observatory for Protected Areas (DOPA)[1] developed by the Joint Research Centre of the European Commission. DOPA is built on web-based technologies, pulling together global datasets that are further processed before being integrated into comparable indicators, which are then shared through web services and applications (Juffe-Bignoli et al. 2024). The outputs can be used to assess, monitor and report the state of and the pressure on protected areas at country, ecoregion and protected area level. DOPA's list of datasets is available here[2].

The report is divided in two main sections: i) the first part describes data repositories assessed and put together for users to have a complete overview of all available knowledge, and ii) the second part digs deeper into the datasets to assess their main characteristics along with a detailed analysis of acquired data. The results are summarized in large and detailed tables, while all relevant information is stored within ZENODO (Kefalas et al. 2025). A critical reflection on the issues of data availability and coverage across Europe is also provided. It is also noted that the R Code via which graphs have been produced is available in the GitLad (project ID: 66131059).

[1] https://dopa.jrc.ec.europa.eu/dopa/. Registration for the full use of services at https://rest-services.jrc.ec.europa.eu

[2] https://rest-services.jrc.ec.europa.eu/services/d6dopa/dopa_43/get_dopa_function_source_list?format=html

2 Assessing the landscape of biodiversity data in Europe and beyond

Over the years, numerous geodatabases have been developed and published, compiling data related to biodiversity and habitats, with diverse foci on taxonomy, spatial distribution, and record types (Ball-Damerow et al., 2019). However, for the offered data to be effectively utilized by experts such as conservationists, planners, policy, and decision-makers, especially at large geographical scales, it is essential to have a clear overview of the potential and limitations of these datasets (Wetzel et al., 2018). For this report, we extracted information which can be used to assess the completeness of the data in terms of coverage, the accuracy of geographical attributes, the methods of data acquisition, as well as the frequency of data updates.

To narrow down this study, **the focus was put on geodatabases with information on species and/or habitats at European level**, including databases covering the marine regions in Europe. Thus, neither land use / land use change data sets nor national databases were systematically screened.

For the aim of this work, to distil information on biodiversity and habitat geodata, both opportunistic and targeted searching processes were followed. Opportunistic searching refers to the process of acquiring data opportunistically during the implementation of other tasks such as literature review. This approach is widely used in ecological studies, especially when gathering data from large geographical regions and from various taxa (Moussy et al., 2022). In parallel, a targeted searching process was implemented, which involves systematically assessing various well-known geodatabases, websites of key organizations (e.g., GBIF), and research projects working on biodiversity data were identified (e.g., GEOBON). In our search we looked for Global and European databases and for them to be included in the catalogue and maintained for further analysis, the following criteria were applied:

1. **Georeferenced data**: The data repositories and datasets must be georeferenced and be provided in any geographical format, such as polygon, line, point, or raster. Alternatively, if providing the dataset in a geographical format is not possible, additional information that can be used for georeferencing purposes must be provided.

2. **Geographical Coverage**: The data repositories and datasets should ideally cover at least the EU-27 Member States. However, in cases where a dataset provides unique information for species and/or habitats, the coverage criterion may be considered flexible or overridden due to the significance of the data.

3. **Availability**: The data repositories and datasets should be publicly accessible or provided upon request.

Once a data repository and dataset meets the criteria mentioned in the previous section, its features are reported in the form of tables (the catalogue is available in ZENODO, Kefalas et al. 2025). It is worth noting that two tables were structured: one presenting the general characteristics of the entire data repository (Table 1) and one presenting attributes related to specific dataset (Table 2). The fields of information extracted per data repository, are described in detail in the metadata tables (Table 1 and 2). For the data organization to be systematic, we applied specific standards to classify the information, where possible. Also, in order to have a better overview of the spatial coverage of the provided information, we compiled map (for each data repository and dataset), which allows to see which parts of Europe are better covered by the data detected, and which areas need more information. Due to the differences among datasets regarding their spatial resolution and format, the level of analysis was based on the reference grid provided by the

European Environmental Agency. Each cell in the grid represents the presence or absence of a dataset, while additional maps presenting a summary of the available dataset were compiled (i.e. how many datasets are available in the cell).

2.1 Metadata description at the data repository level

The fields of information extracted per data repository is given in Table 1. To ensure systematic organization of the data repositories' metadata, we follow specific standards for terminology and classification whenever possible. The detailed information extracted at the data repository level is given in Table 1.

Table 1. Metadata information for data repositories explored.

Field Name	Description	Input/Classification
Index	ID indexing using the acronym of the data repository.	
Data repository name	Name of data repository.	
Data repository description	Description (definition) of data repository.	
Ownership	Ownership type of data repository.	EU (for data owned by the EU) Project-based (for data that occurred as an outcome of a project) National dataset (data with a nation-wide focus) Institutionally owned (data owned by wider than EU institutions, such as IUCN)
Reference	Exact reference of the data repository.	
Host name	Host institute/organization.	
Theme	It identifies whether the data repository targets species or habitats or both or if it provides a more generic knowledge on the environment.	Species Habitat Multiple Species' habitat Unspecified
Species class (If level of organization is species)	Data repositories are classified per taxonomic class, according to the EU Article 17 and Article 12 categorization.	Amphibians Arthropods Fish Mammals Molluscs Non-vascular plants Other invertebrates Reptiles Vascular plants Birds Multiple/Other None
Realm	It classifies the basic components of the biosphere that are covered by the data repository/data according to the IUCN Ecosystem Typology[3].	Terrestrial Marine Freshwater Multiple (Transitional realms)

[3] https://global-ecosystems.org/page/typology

Basis of record	Methods/procedures used for the data acquisition.	Expert observation (biodiversity observations by field experts) Citizen science (public participation in scientific research or community-based monitoring) Machine observation (sensor-based monitoring including cameras, gps trackers, sound recorders, remoter sensing/satellite data) Modelling (species distribution/occurrences modelling approaches) Expert knowledge (Expert-based knowledge ranking not based on field observation) Multiple Unspecified
Spatial format	It indicates the spatial format of the data repository/data.	Raster Polygon Point Line Table Multiple No-spatial format
File format	It indicates the file format of the data contained in the data repository [4].	GeoTIFF (.tiff) Shapefile (.shp) Table (.xls or .csv) Access Keyhole Markup Language (.kml) ASCII Web Map Service (WMS)
Coverage	The geographical coverage of the data contained in the data repository.	Global European Sub-regional Member state/National Cross-border Subnational
Projection	The geographical projection of the data contained in the data repository.	WGS 1984 ETRS 1989 Multiple
Spatial resolution	The spatial resolution of the data contained in the data repository.	
Temporal range	Indicates the temporal range of the data contained in the data repository.	Start date (year) – end date (year) Unspecified
Temporal resolution	Identifies the temporal resolution of the data contained in the data repository.	Annual Monthly Multiple Unspecified
Update frequency	The frequency in which the data repository is updated.	Annual Irregular/as needed Multiple

[4] https://gisgeography.com/gis-formats/

		6-month No update Unspecified
Access points / URL	The URL where the data repository can be downloaded.	
Permission	Indicate the permission under which the data repository is provided.	Open access (including data provided by request) Restricted use Commercial
Licence	Indicate the specific license under which the data repository is provided under the Creative Commons categorization[5].	PUBLIC DOMAIN CC BY CC BY-SA CC-BY-ND CC-BY-NC CC-BY-NC-SA CC-BY-NC-ND EEA data policy Unspecified

Source: this report.

2.2 Metadata description at the dataset level

The fields of information extracted per dataset featured within each data repository, are described in detail in the metadata table (Table 2). For the dataset organization to be systematic, we applied specific standards to classify the information, where possible. It is important to note at this point, that for ease of summarization of the information, we mainly classified the information related to biodiversity attributes into Species, Habitat and Species' habitat related datasets. For Species relevant datasets, we included both datasets that target species groups (e.g., mammals) but also datasets that focus on specific taxa, as these usually were built for species taxa of specific importance and relevance for biodiversity assessments. The Habitat type information, referring to more generic classifications (Drakou et al., 2011) of e.g., vegetation types or habitat types as referred to in the EU Habitats Directive (92/43/EEC), while information on Species habitats related to species-specific habitats such as, datasets on Essential Fish Habitat at the EU level[6].

Table 2. Metadata information for data explored.

Field Name	Description	Input/Classification
Index	ID indexing using the acronym of the dataset.	Suffix HM= Marine Habitat HT: Terrestrial Habitat HMu: Multiple/Transitional Habitat SM: Marine Species, ST: Terrestrial/Freshwater Species SMu: Species in multiple/transitional realms
Data repository	Name of data repository.	
Data description	Description (definition) of data.	
Ownership	Ownership type of the dataset.	EU (for data owned by the EU) Project-based (for data that occurred as an outcome of a project)

5 https://creativecommons.org/licenses/
6 http://emis.jrc.ec.europa.eu/satellite/

		National dataset (data with a nation-wide focus) Institutionally owned (data owned by wider than EU institutions, such as IUCN)
Reference	Exact reference of the data.	
Host name	Host institute/organization.	
Levels of organization	It identifies whether the data targets species or habitats or both or if it provides a more generic knowledge on the environment.	Species Habitat Species' habitat Multiple Unspecified
Species class (If level of organization is species)	Data are classified per taxonomic class, according to the EU Article 17 and Article 12 categorization.	Amphibians Arthropods Fish Mammals Molluscs Non-vascular plants Other invertebrates Reptiles Vascular plants Birds Multiple/Other None
Realm	It classifies the basic components of the biosphere that are covered by data according to the IUCN Ecosystem Typology [7].	Terrestrial Marine Freshwater Multiple
Basis of record	Methods/procedures used for the data acquisition.	Expert observation (biodiversity observations by field experts) Citizen science (public participation in scientific research or community-based monitoring) Machine observation (sensor-based monitoring including cameras, gps trackers, sound recorders, remoter sensing/satellite data) Modelling (species distribution/occurrences modelling approaches) Expert knowledge (Expert-based knowledge ranking not based on field observation) Multiple Unspecified
Spatial format	It indicates the spatial format of the data.	Raster Polygon Point Line Table Multiple No-spatial format
File format	It indicates the file format of the data[8].	GeoTIFF (.tiff)

[7] https://global-ecosystems.org/page/typology
[8] https://gisgeography.com/gis-formats/

		Shapefile (.shp) Table (.xls or .csv) Access Keyhole Markup Language (.kml) ASCII Web Map Service (WMS)
Coverage	The geographical coverage of the data.	Global European Sub-regional Member state/National Cross-border Subnational
Projection	The geographical projection of the data.	WGS 1984 ETRS 1989
Spatial resolution	The data spatial resolution.	
Temporal range	Indicates the temporal range of the data.	Start date (year) – end date (year) Unspecified
Temporal resolution	Identifies the temporal resolution of the data.	Annual Monthly Multiple Unspecified
Update frequency	The frequency in which the data is updated.	Annual Irregular/as needed Multiple 6-month No update Unspecified
Access points / URL	The URL where the data can be downloaded.	
Permission	Indicate the permission under which the data is provided.	Open access (including data provided by request) Restricted use Commercial
Licence	Indicate the specific license under which the data is provided under the Creative Commons categorization[9].	PUBLIC DOMAIN CC BY CC BY-SA CC-BY-ND CC-BY-NC CC-BY-NC-SA CC-BY-NC-ND EEA data policy Unspecified
Strategy	Link to specific EU directives, frameworks, strategies, agendas, etc.	92/43/EEC MSFD WFD EU Restoration Law Sustainable Development Goals

Source: this report.

[9] https://creativecommons.org/licenses/

3 Description of explored data repositories and datasets

3.1 Basic description: Data repository level

Following the search strategy that was described in Chapter 2, we generated a catalogue of data repositories providing biodiversity information in Europe. Overall, the data repositories that met the eligibility criteria described in Chapter 2, were 29 in total (Table 3).

Table 3. Eligible datasets included in the catalogue.

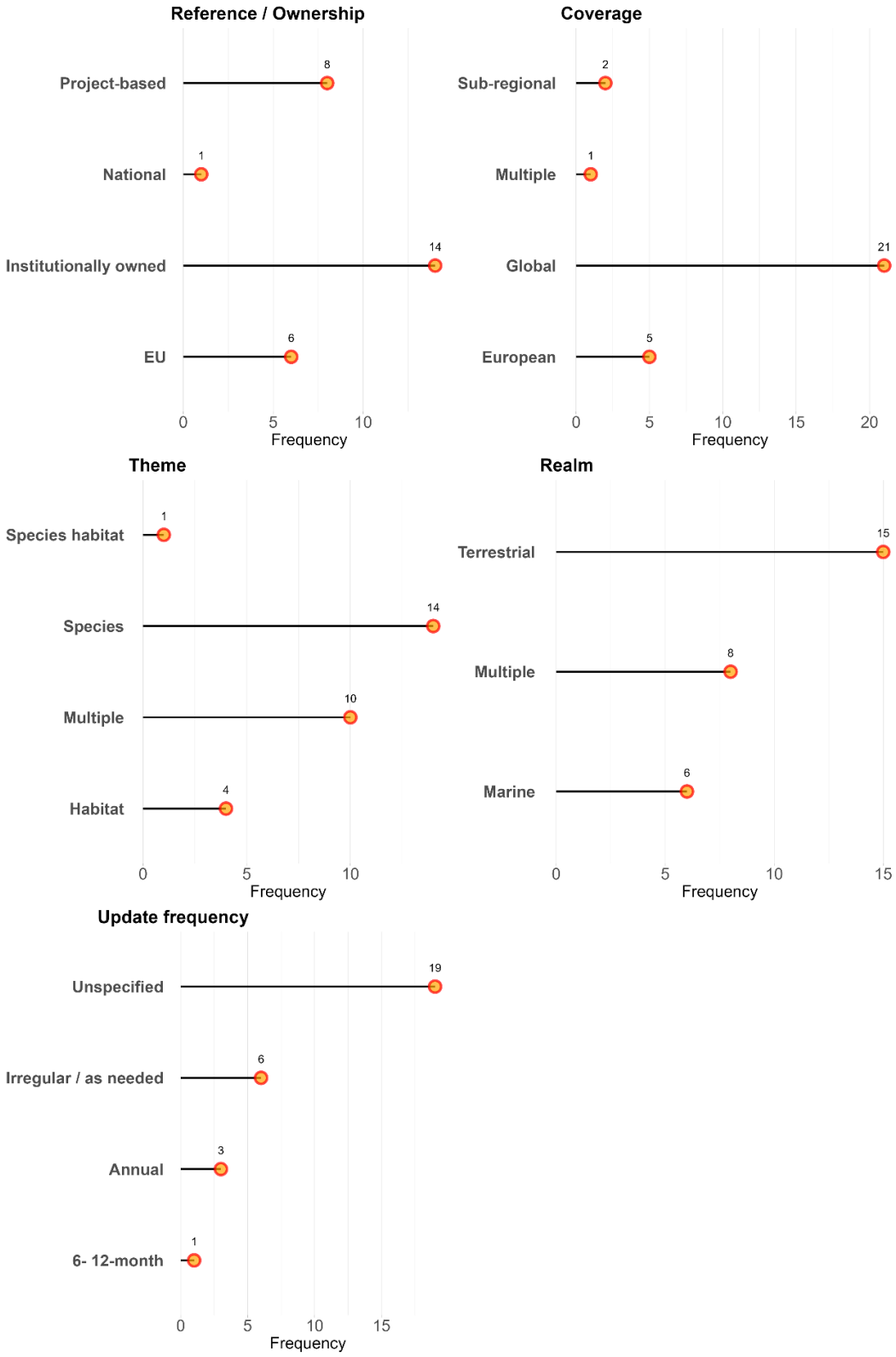
Index	Data repository
AGI	Areas of global importance for conserving terrestrial biodiversity, carbon, and water
ARCTOS	ARCTOS Collaborative Collection Management Solution
BIEN	Botanical Information and Ecology Network
BRDI	BirdLife International
EEAD	European Environment Agency Datasets
OPFish.JRC	Ocean Productivity available to fish
EVA	European Vegetation Survey
GABI	Global Ant Biodiversity Informatics database
GBIF	Global Biodiversity Information Facility
GIFT	Global Inventory of Floras and Traits
ICES.CIEM	International Council for the Exploration of the Sea
IUCN	International Union for Conservation of Nature's
IUCN.MMPATF	IUCN- Marine Mammal Protected Areas Task Force
NHM.BTE	Biodiversity Trends Explorer
OBIS	Ocean Biodiversity Information System
OSPAR	Oslo and Paris Conventions
UNEP.WCMC	UNEP WCMC Ocean data viewer
UoM.FCC	Forest Cover Change
USGS	World Terrestrial Ecosystems
VASC	Global patterns of vascular plant alpha diversity
WWF	Terrestrial Ecoregions of the World
LPI	Living Planet Index
BioTIME	BioTIME
eMammal	eMammal
EWS	Main European woody species
TreeAtlas	The European Atlas of Forest Tree Species
EFI	Tree species maps for European forests
EmodNET	European Marine Observation and Data Network
HELCOM	Baltic Marine Environment Protection Commission

Source: this report.

14 data repositories are owned and provided by large institutions and organizations such as the Europe Environmental Agency (EEA), Joint Research Centre (JRC), United Nations Environmental Programme - World Conservation Monitoring Centre (UNEP-WCMC), and others. Among those explored, 8 data repositories are project-based. Only 1 data repository, namely the Biodiversity Trends Explorer is owned by a national organization, the UK Natural History Museum. Most of the data repositories explored cover at least the EU-27 region, with 21 repositories having global coverage and 5 focusing on EU-27. 2 repositories, OSPAR and the Baltic Marine Environment Protection Commission (HELCOM), although limited to sub-regional coverage, are included in the catalogue due to the uniqueness and significance of their contained data (Figure 1).

Regarding the theme of the data repositories, 19 of them are exclusively oriented towards species, habitat or species habitat (14, 4, and 1, respectively), and 10 provide data for both species and habitats (labelled as "multiple"). In terms of realm, half of the data repositories 15 focus on terrestrial ones, 6 on marine, and 8 on both terrestrial and marine realms (Figure 1). Finally, most of the repositories do not provide information about their update frequency. However, out of the 10 data repositories that declare updates, 6 are updated partially, meaning that only specific data within the repositories are updated, rather than the entire infrastructure. Additionally, 3 datasets are updated annually and 1 every six months (Figure 1).

Figure 1. Main characteristics of considered data repositories in terms of ownership status and geographic coverage, theme they deal with, biotic realm and frequency update of the repository.



Source: this report.

3.1.1 Data repositories related to habitats

Among the detected data repositories, 4 provide information related to habitat (Table 4).

Regarding the data repositories related to habitat, it is worth noting that only 1 repository, Ocean Productivity Available to fish– OPFish.JRC, provides data for marine ecosystems, while the remaining 3, Forest Cover Change – UoM.FCC, World Terrestrial Ecosystems – USGS, and Terrestrial Ecoregions of the World – WWF, provide data for terrestrial ones (Table 4 and Figures 2). Data contained in the habitat related repositories were produced using modelling procedures and have global coverage. Except the WWF dataset, which is provided as polygon, the remaining 3 data sources are provided in raster format, with their resolution varying from 30m for UoM.FCC to 5km for OPFish.JRC (Table 5).

About data accessibility/availability, all data are open access, with the CC BY license for the dataset "Forest Cover Change", while a specific license for the remaining 3 dataset was not specified (Table 6). As for the spatial distribution of the data repositories they all met the coverage criterion of EU-27, where 3 repositories related to terrestrial habitats are available for the entire European territory, and 1 marine habitat dataset is available for all European seas (Figure 2).

Table 4. Data repositories providing data related to habitats.

Index	Data repository name	Ownership	Reference	Realm	Access points / URL
OPFish.JRC	Ocean Productivity available to fish	EU	Druon 2021, JRC	Marine	https://data.jrc.ec.europa.eu/dataset/a82f0745-6181-4918-9aef-e4dee6149ac6
UoM.FCC	Forest Cover Change	Institutionally owned	Hensen et al. 2013, Science	Terrestial	https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.7.html
USGS	World Terrestrial Ecosystems	Institutionally owned	USGS	Terrestial	https://rmgsc.cr.usgs.gov/outgoing/ecosystems/Global/
WWF	Terrestrial Ecoregions of the World	Institutionally owned	Olson et al. 2001, Bioscience	Terrestial	https://www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world

Source: this report.

Table 5. Spatial characteristics for data repositories related to habitats.

Index	Basis of record	Spatial format	Coverage	Projection	Spatial resolution
OPFish.JRC	Modelling	Raster	Global	WGS 1984	5km
UoM.FCC	Modelling	Raster	Global	WGS 1984	30m
USGS	Modelling	Raster	Global	WGS 1984	250m
WWF	Modelling	Shapefile	Global	WGS 1984	

Source: this report.

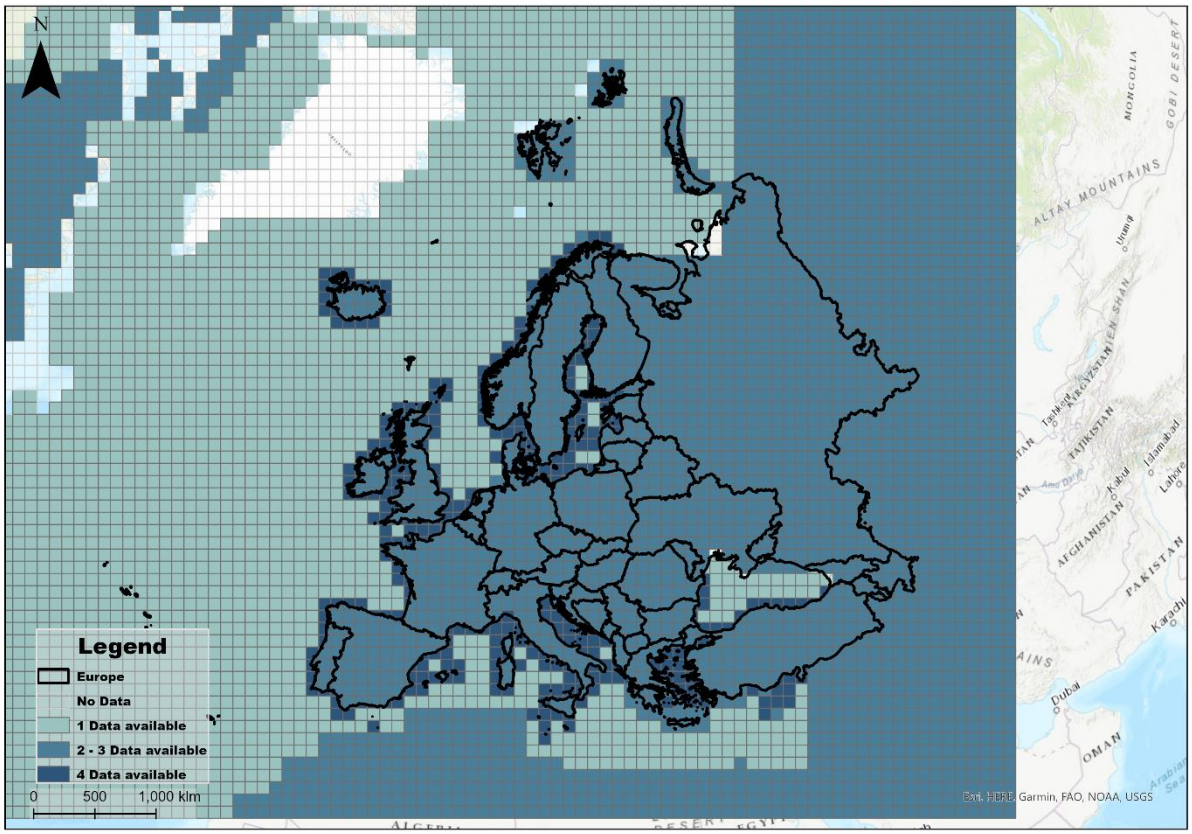
Table 6. Permission and licence for the data repositories related to habitats.

Index	Permission	Licence
OPFish.JRC	Open access	Unspecified
UoM.FCC	Open access	CC BY

USGS	Open access	Unspecified
WWF	Open access	Unspecified

Source: this report.

Figure 2. Geographical density of available data repositories related to habitat at the European scale.



Source: this report.

3.1.2 Data repositories related to species specific information

14 data repositories exclusively provide information related to species that met the criteria and were considered for inclusion in the catalogue (Table 7 and 8). The vast majority of the data repositories (10 repositories) focus on terrestrial ecosystems, while there are 4 repositories that include species from both marine and terrestrial ecosystems (marked as multiple) (Tables 7 and 8 and Figure 3). In parallel, 10 data repositories are taxa-oriented as they include data related to a specific taxon, while 3 repositories contain data for more than one taxon. Additionally, the catalogue includes 1 data repository, namely Biodiversity Trends Explorer – NHM.BTE, which does not focus on a specific taxon but provide composite biodiversity indices (Table 7). For the taxa-oriented data repositories, vascular plants are mostly represented (6 repositories), followed by mammals (2 repositories), invertebrates, and birds (each with 1 repository). Most of the species' data integrated in the repositories were formed using modelling procedures (6 repositories), while 5 datasets were created through expert observations. Regarding their spatial characteristics, 11 data repositories show the global distribution of the examined species, while 3 repositories focus on Europe only (Table 8).

In Figure 3, the spatial coverage of all available data repositories is presented, and it can be observed that 3 is a higher availability of data in western and central Europe. Specifically, data retrieved from the Living Planet Index – LPI and BioTime, both focusing on multiple taxa, have a higher number of records in those areas compared to the regions in Eastern Europe. Also, it should be noted that maps for the datasets ARCTOS, BIEN, BRDI, and eMammal were not included or presented due to temporary unavailability of data sources at the time of data acquisition, or due to permission/licensing restrictions. Finally, for species-related datasets, with the exception of the BirdLife International – BRDI dataset, all data are open access, including those provided upon request.

Table 7. Data repositories providing data related to species.

Index	Data repository name	Ownership	Reference	Class	Realm	Access points / URL
ARCTOS	ARCTOS Collaborative Collection Management Solution	Project-based	ARCTOS	Mammals	Terrestrial	https://arctos.database.museum/
BIEN	Botanical Information and Ecology Network	Project-based	BIEN	Vascular plants	Terrestrial	https://bien.nceas.ucsb.edu/bien/biendata/
BRDI	BirdLife International	Institutionally owned	Birdlife International	Birds	Multiple	http://datazone.birdlife.org/home
EVA	European Vegetation Survey	EU	Chytrý et al.2016, Applied Veg. Science	Vascular plants	Terrestrial	http://euroveg.org/eva-database
GABI	Global Ant Biodiversity Informatics database	Institutionally owned	Guénard et al. 2017, Myrmecological News	Invertebrates	Terrestrial	https://antmaps.org/about.html
GIFT	Global Inventory of Floras and Traits	Project-based	Cai et al. 2023, New Phytologist	Vascular plants	Terrestrial	https://gift.uni-goettingen.de/shiny/predictions/
DiIUCN	IUCN	Institutionally owned	IUCN	Multiple	Multiple	https://www.iucnredlist.org/resources/spatial-data-download
NHM.BTE	Biodiversity Trends Explorer	National	Newbold et al. 2016, Science 353	Other	Terrestrial	https://data.nhm.ac.uk/dataset/global-map-of-the-biodiversity-intactness-index-from-newbold-et-al-2016-science 2. https://data.nhm.ac.uk/dataset/bii-bte
VASC	Global patterns of vascular plant alpha diversity	Project-based	Sabatini et al. 2022, Nature Communication	Vascular plants	Terrestrial	https://idata.idiv.de/ddm/Data/ShowData/3506?version=70
LPI	Living Planet Index	Institutionally owned	WWF-ZSL	Multiple	Multiple	https://www.livingplanetindex.org/search

BioTIME	BioTIME	Project-based	Dornelas et al. 2018, Global Ecol Biogeography	Multiple	Multiple	https://biotime.st-andrews.ac.uk/download.php
eMammal	eMammal	Project-based	Multiple	Mammals	Terrestrial	https://emammal.si.edu/analysis/data-download
EWS	Main European woody species	Project-based	Caudullo et al. 2022, Mendeley Data	Vascular plants	Terrestrial	https://data.mendeley.com/datasets/hr5h2hcgg4
EFI	Tree species maps for European forests	EU	Brus et al. 2011 Eu Jou.of For.Resea., Hengeveld et al. 2011, Ecol. & Soci., Nabuurs 2009, Alte. & Euro Fore. Insti., Shuck et al. 2002, Eur. Fore. Insti., Troltzsch et al. 2009, Fore. Ecol & Mana.	Vascular plants	Terrestrial	https://efi.int/knowledge/maps/treespecies

Source: this report.

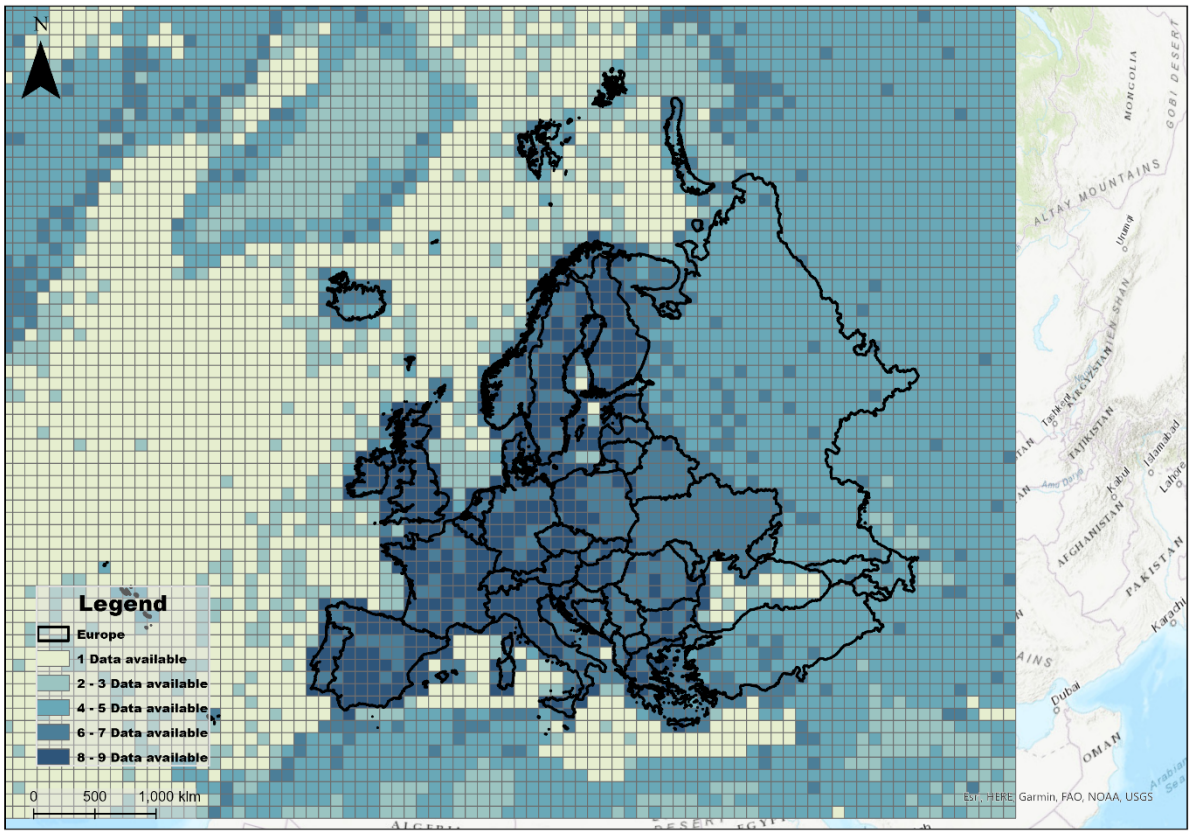
Table 8. Spatial attributes, permissions and licence for data repositories related to species.

Index	Basis of record	Spatial format	Coverage	Projection	Permission	Licence
ARCTOS	Unspecified		Global	Unspecified	Open access	Unspecified
BIEN	Expert observation	Multiple	Global	WGS 1984	Open access	CC BY-NC-ND
BRDI	Unspecified	Polygon	Global	WGS 1984	Restricted use	Unspecified
EVA	Expert observation	Table	European	WGS 1984	Open access	Unspecified
GABI	Expert knowledge	Polygon	Global	WGS 1984	Open access	Unspecified
GIFT	Modelling	Multiple	Global	WGS 1984	Open access	Unspecified
IUCN	Modelling	Polygon	Global	WGS 1984	Open access	Unspecified
NHM.BTE	Modelling	Raster	Global	WGS 1984	Open access	CC BY
VASC	Modelling	Raster	Global	WGS 1984	Open access	CC BY
LPI	Expert observation	Point	Global	WGS 1984	Open access	Unspecified
BioTIME	Expert observation	Point	Global	WGS 1984	Open access	Unspecified
eMammal	Multiple		Global	WGS 1984	Open access	Unspecified

EWS	Modelling	Multiple	European	WGS 1984	Open access	CC BY
EFI	Modelling	Raster	European	ETRS 1989	Open access	Unspecified

Source: this report.

Figure 3. Geographical density of available data repositories related to species at the European scale.



Source: this report.

3.1.3 Data repositories related to both species and habitat information

As mentioned above, 10 repositories provide data for both habitat and species (Tables 9 and 10). These repositories are primarily hosted by international institutions such as the European Environmental Agency – EEA, The UN Environment Programme World Conservation Monitoring Centre – UNEP-WCMC, and the Baltic Marine Environment Protection Commission – HELCOM. They serve as repositories for data produced from various projects, actions, or tasks. While these data sources provide a wide range of data, there are 4 data repositories that exclusively deliver data for the marine realm, such as the International Council for the Exploration of the Sea – ICES.CIEM, the Ocean Biodiversity Information System – OBIS, the European Marine Observation and Data Network – EmodNET, and HELCOM. Most of these repositories (8 repositories) do not have a specific basis of record, as it depends on the actual data (where a data linked with species or habitat), nor a specific spatial format. The data contained in these repositories is open access, and it can be either directly downloaded or obtained upon request (Table 10).

Regarding the spatial distribution of the provided data, although European coverage is an essential criterion, two data repositories, OSPAR and HELCOM, provide data at a sub-regional scale,

specifically for the European part of the Atlantic Ocean and the Baltic Sea, respectively (Figure 4). The consideration and integration of these data sources rely on the significance and uniqueness of the offered data, which are essential for various management and conservation actions.

Table 9. Data repositories providing data related to both habitats and species.

Index	Data repository	Ownership	Reference	Realm	Access points / URL
AGI	Areas of global importance for conserving terrestrial biodiversity, carbon, and water	Project-based	Jung et al. 2021, Nature	Terrestrial	https://zenodo.org/record/5006332#.Y-oHtHZBxD8
EEAD	European Environment Agency Datasets	EU	EEA	Multiple	https://www.eea.europa.eu/data-and-maps/data#c0=5&c11=&c5=all&b_start=0
GBIF	Global Biodiversity Information Facility	Institutionally owned	Multiple	Multiple	https://www.gbif.org/dataset/search
ICES.CIEM	International Council for the Exploration of the Sea	Institutionally owned	Multiple	Marine	http://gis.ices.dk/geonetwork/srv/eng/catalog.search#/home
OBIS	Ocean Biodiversity Information System	Institutionally owned	OBIS	Marine	https://obis.org/data/access/
OSPAR	Oslo and Paris Conventions Data	Institutionally owned	Multiple	Multiple	https://odims.ospar.org/en/datastreams/
UNEP.WCMC	UNEP-WCMC Ocean data viewer	Institutionally owned	Multiple	Multiple	https://data.unep-wcmc.org/
TreeAtlas	The European Atlas of Forest Tree Species	EU	Mauri et al. 2016, Pub. Office of EU	Terrestrial	https://forest.jrc.ec.europa.eu/en/european-atlas/atlas-data-and-metadata/
EmodNET	European Marine Observation and Data Network	EU	Multiple	Marine	https://emodnet.ec.europa.eu/geonetwork/srv/eng/catalog.search#/search?resultType=details&sortBy=sortDate&result&from=1&to=20
HELCOM	Baltic Marine Environment Protection Commission	Institutionally owned	Multiple	Marine	https://maps.helcom.fi/website/mapservice/index.html

Source: this report.

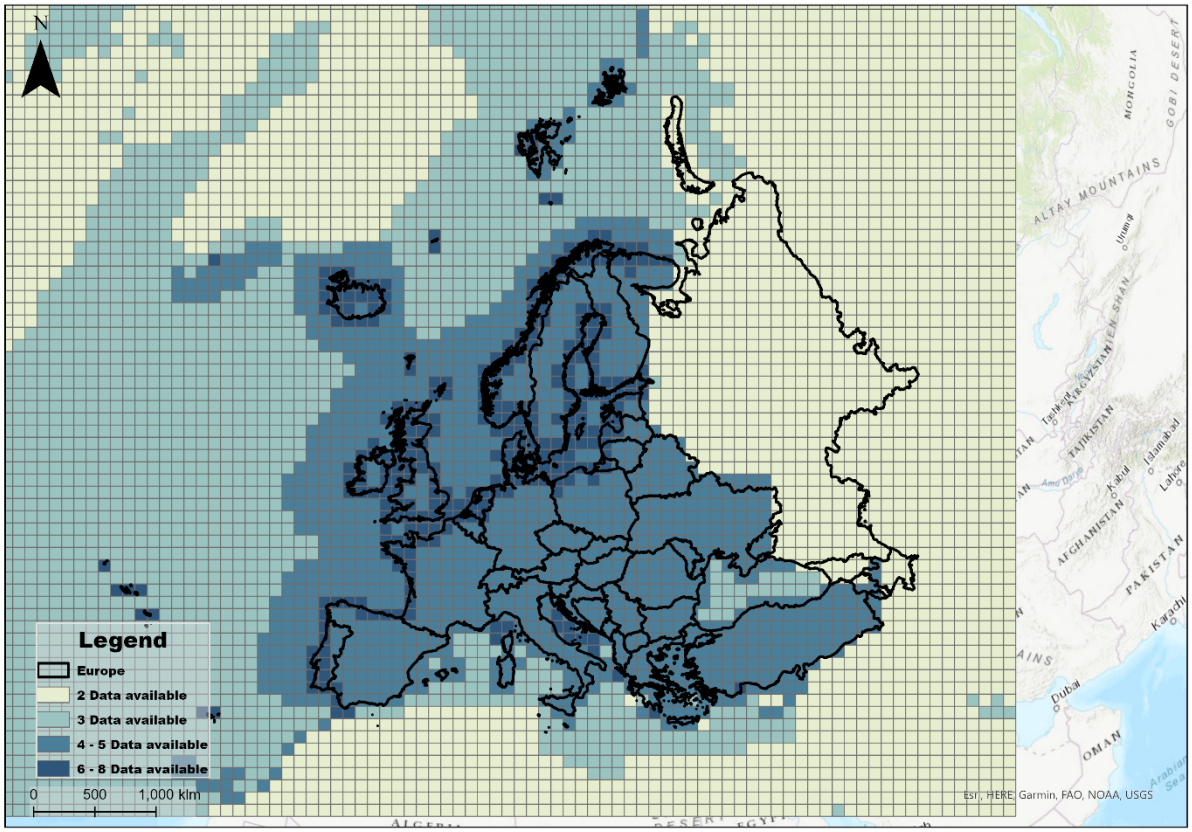
Table 10. Spatial characteristics, permissions and licence for data repositories related to both habitats and species.

Index	Basis of record	Spatial format	Coverage	Projection	Permission	Licence
AGI	Modelling	Raster	Global	WGS 1984	Open access	CC BY-SA
EEAD	Multiple	Multiple	Multiple	Multiple	Open access	EEA data policy
GBIF	Multiple	Multiple	Global	WGS 1984	Open access	CC BY

ICES.CIEM	Multiple	Multiple	Global	WGS 1984	Open access	Unspecified
OBIS	Multiple	Multiple	Global	WGS 1984	Open access	CC BY
OSPAR	Multiple	Multiple	Sub-regional	WGS 1984	Open access	CC0
UNEP.WCMC	Multiple	Multiple	Global	WGS 1984	Open access	CC BY-NC
TreeAtlas	Modelling	Raster	European	ETRS 1989	Open access	Unspecified
EmodNET	Multiple	Multiple	European	Unspecified	Open access	Unspecified
HELCOM	Multiple	Multiple	Sub-regional	WGS 1984	Open access	Unspecified

Source: this report.

Figure 4. Geographical density of available data repositories related to both species and habitat at the European scale.

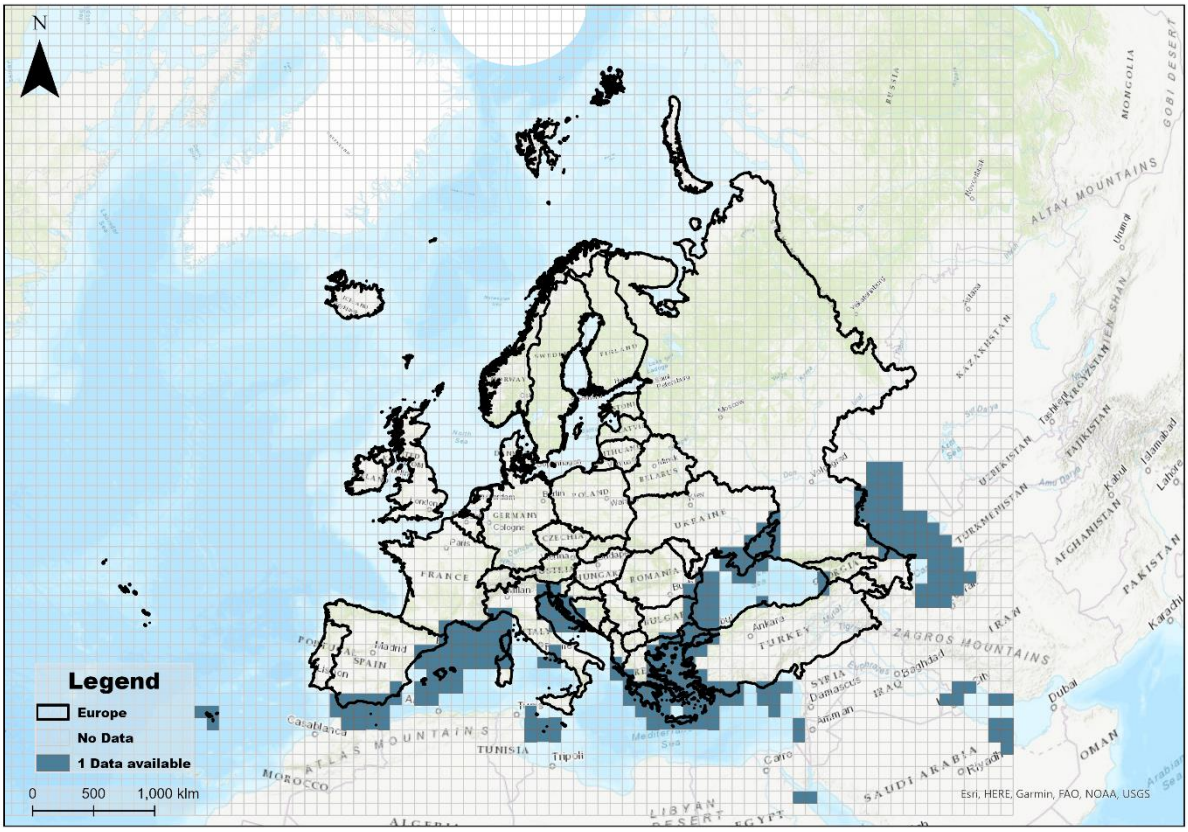


Source: this report.

3.1.4 Data repositories related to species' habitat

The only data repository that provides data related to species' habitats is the Marine Mammal Protected Areas Task Force (MMPATF), owned by the International Union for Conservation of Nature (IUCN). This repository provides data outputting by a modelling procedure that covers significant areas for marine mammals around the world and is provided as a polygon (shapefile or KML). The IUCN.MMPATF repository is updated on a 6-12 monthly basis and is open access under the CC BY-NC-SA licence. As shown in Figure 5, in Europe, the repository covers areas in the Mediterranean Basin as well as the Black Sea.

Figure 5. Geographical density of available data repository related to species' habitat at the European scale.



Source: this report.

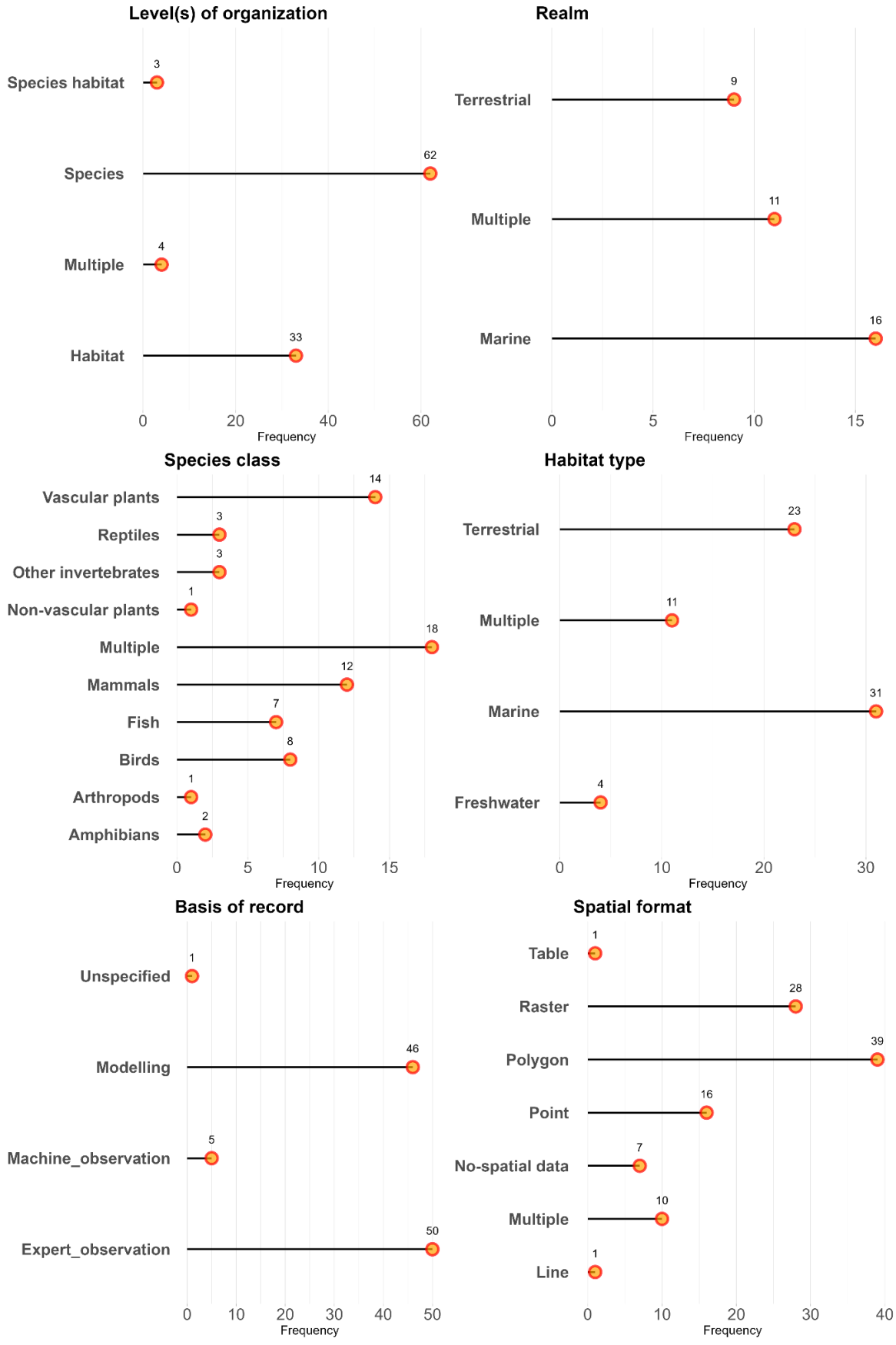
3.2 Basic description: Dataset level

At the actual dataset level, 102 datasets were assessed and included in the catalogue. The majority of the datasets referred to species (62 datasets), followed by datasets related to habitats (33 datasets). Additionally, 4 datasets marked as multiple/others presenting indices related to biodiversity, and 3 datasets labelled as species' habitat (Figure 6). Focusing on species datasets, the most representative species groups were vascular plants (14 datasets), followed by mammals (12 datasets), and birds (8 datasets). Non-vascular plants and arthropods were the least represented species groups, with only 1 dataset source for each. Additionally, 18 datasets have been marked as multiple, as their sources provide data without indicating specific taxa. Regarding the species' habitats, the majority of the datasets referred to marine ecosystems (31 data), while 23 datasets were related to terrestrial ecosystems, and 4 datasets related to freshwater ecosystems. Marine ecosystems were also more represented than others in terms of realm, with 16 data types focusing on marine habitats, compared to 9 linked with terrestrial ecosystems, and 11 on habitats for both marine and terrestrial ecosystems (Figure 6). Also, it is worth noting that in the cases of the 31 species' habitat datasets, the habitat type is marine. The larger number within the marine habitats, has to do with the fact that in many cases these refer to habitats of specific species and not generic habitat information. These datasets offer data for various levels of species organization, such as benthos and mammals, as well as various functions of marine ecosystems, including biodiversity conditions and marine ecosystem health. In parallel, although the terrestrial datasets include a large amount of information at the level of taxa, the level of information in the marine

datasets include data at the species level resulting in the higher amount of data provided for the marine environment.

Almost half of the datasets within the assessed repositories (50 datasets) were acquired through expert observations, compared to 46 datasets that were produced via modelling procedures. Additionally, there were 5 datasets extracted through machine observations (including remote sensing techniques) and 1 dataset where the basis of record was not specified. Finally, the polygon format was the most common spatial format used to deliver the datasets, with 39 datasets delivered in this format. This was followed by raster and points, with 28 and 16 datasets, respectively (Figure 6).

Figure 6. Summary of the datasets included in the catalogue.



Source: this report.

3.2.1 Habitats: Marine

In Tables 11 and 12, as well as in Figure 7, the datasets related to marine habitats and their spatial distribution are presented. Specifically, 13 datasets were assessed and included in the catalogue, all owned and distributed by large institutions and organizations such as EEA or UNEP-WCMC, among others. The selected datasets can be classified into two groups. The first group contains datasets that offer important insights of European seas, such as marine ecosystem health and ocean productivity. The second group contains datasets that focus on specific habitat elements, such as the distribution of coral reefs or the identification of important marine mammal areas (Table 11).

The basis of record for these datasets varies, with half of the datasets resulting from modelling procedures and the other half retrieved through expert or machine observations (Table 12). In terms of coverage, the datasets provided by EEA extends across Europe, offering important information about the conditions for all European seas. On the other hand, datasets retrieved by UNEP-WCMC varies in terms of coverage, as these datasets are more focused on specific habitat types and characteristics, such as the seagrass biome or coral reefs. Finally, the catalogue includes datasets offered by HELCOM, which focuses on a regional level in the Baltic Sea, where datasets are systematically recorded and distributed. At the habitat level, NATURA 2000 habitats and broad-scale habitats are considered by this data source.

Table 11. Datasets included in the catalogue related to marine habitat.

Index	Data repository	Data short description	Reference
EEAD.HM1	EEAD	Integrated classification of biodiversity condition in Europe's seas	EEA
EEAD.HM2		Marine Ecosystem health	EEA
EEAD.HM3		Marine waters used in MSFD	EEA
OPFish.JRC.HM1	OPFish	Ocean Productivity available to Fish	Druon 2021, JRC
UNEP.WCMC.HM1	UNEP.WCMC	Modelled Global Distribution of the Seagrass Biome	Jayathilake & Costello 2018 Biol. Cons.
UNEP.WCMC.HM2		Global Distribution of Coral Reef	UNEP-WCMC 2021UNEP-WCMC, IMaRS-USF 2005, Spalding et al 2001 Uni. Cal. Press
UNEP.WCMC.HM3		Global Distribution of Saltmarshes	Mcowen et al. 2017 Biodiv. Data Journal
UNEP.WCMC.HM4		Global Distribution of Tidal Flat Ecosystems	Murray et al. 2019 Nature
EmodNET.HM1	EmodNET	EUSeaMap Baltic & Mediterranean	IFREMER
EmodNET.HM2		Coralligenous in the Mediterranean	Joint Nature Conservation Committee
EmodNET.HM3		Biogenic substrate in Europe	Joint Nature Conservation Committee
HELCOM.HM1	HELCOM	Broadscale habitats	HELCOM HOLAS 2 Dataset 2017
HELCOM.HM2		Natura 2000 habitats	DG ENV - EEA

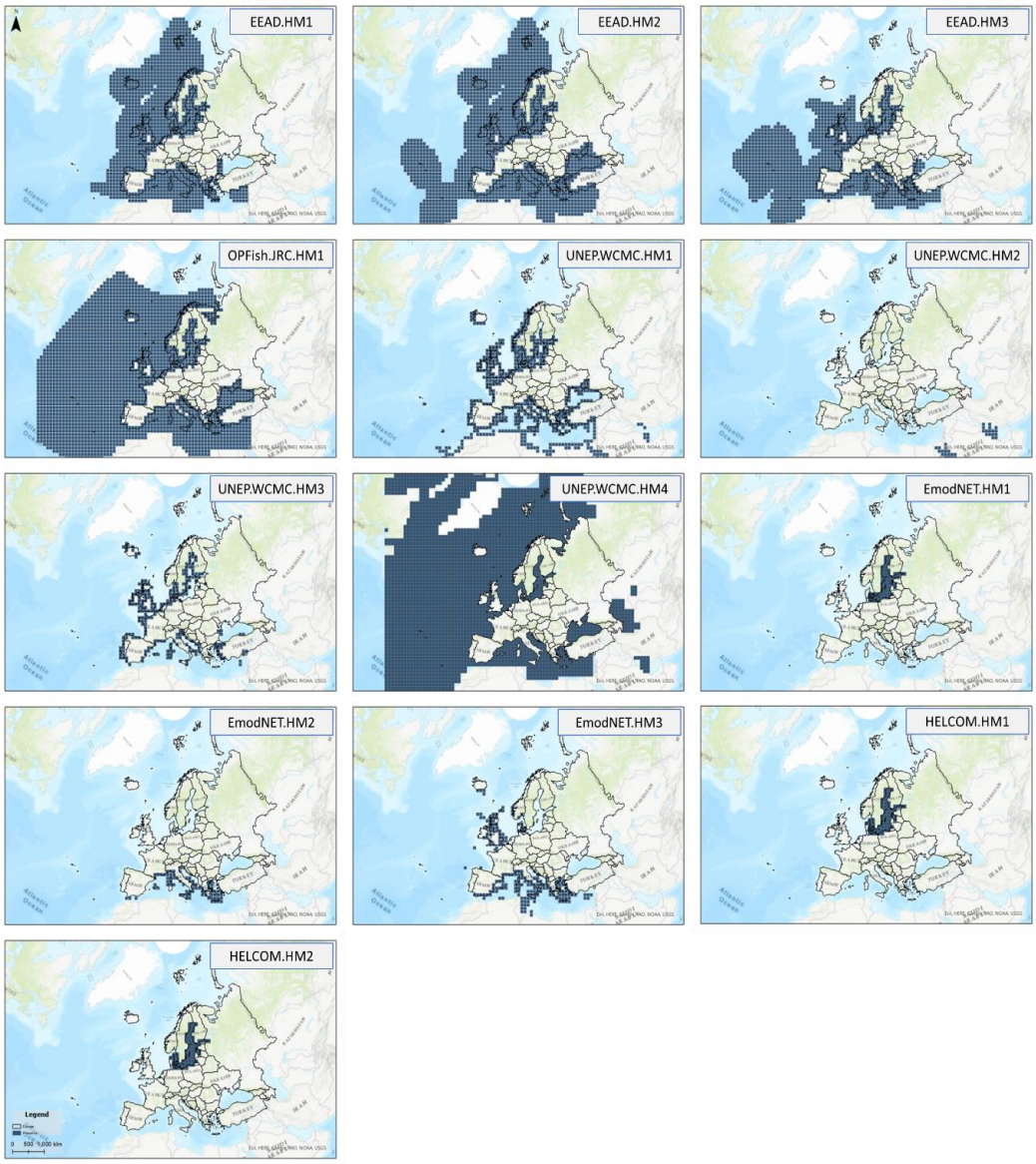
Source: this report.

Table 12. Spatial characteristics for the datasets related to marine habitat.

Index	Basis of record	Spatial format	File format	Coverage	Projection	Spatial resolution
EEAD.HM1	Expert observation	Polygon	Shapefile	European	ETRS 1989	100Km
EEAD.HM2	Modelling	Polygon	Shapefile	European	WGS 1984	>20km
EEAD.HM3	Modelling	Polygon	Shapefile	European	ETRS 1989	Unspecified
OPFish.JRC.HM1	Modelling	Raster	GeoTIFF	Global	WGS 1984	5km
UNEP.WCMC.HM1	Modelling	Polygon	Shapefile	Global	WGS 1984	Unspecified
UNEP.WCMC.HM2	Machine observation	Multiple	Shapefile	Global	WGS 1984	Unspecified
UNEP.WCMC.HM3	Expert observation	Multiple	Shapefile	Global	WGS 1984	Unspecified
UNEP.WCMC.HM4	Machine observation	Raster	GeoTIFF	Global	WGS 1984	30m
EmodNET.HM1	Modelling	Polygon	Shapefile	Sub-regional	WGS 1984	Unspecified
EmodNET.HM2	Expert observation	Polygon	Shapefile	European	WGS 1984	Unspecified
EmodNET.HM3	Expert observation	Polygon	Shapefile	European	WGS 1984	Unspecified
HELCOM.HM1	Expert observation	Raster	WMS	Sub-regional	WGS 1984	1km
HELCOM.HM2	Modelling	Multiple	WMS	Sub-regional	WGS 1984	1km

Source: this report.

Figure 7. Available datasets related to marine habitats.



Source: this report.

3.2.2 Habitats: Terrestrial

The selected datasets for terrestrial habitats are presented in Tables 13 & 14, as well as in Figure 8. Similar to marine habitats, most of the data were acquired from European data sources such as EEA and JRC. In general, the datasets encompasses comprehensive information about habitats, with two of them, namely The World's Terrestrial Ecosystems (USGS.HT1) and Terrestrial Ecoregions of the World (WWF.HT1) being considered as ready-to-use habitat layers, while the TreeAtlas database, provided by JRC, offers habitat suitability maps for each tree species across Europe (Figure 8). In addition to the aforementioned more species-specific habitat layers, the catalogue includes datasets, in form of indices, showing the richness of tree species and the naturalness of farmlands. Regarding the basis of record, all spatial datasets have been produced using modelling techniques and are provided in raster format (with the exception of WWF.HT1, which is provided as a polygon). As for the dataset coverage, UoM.FCC.HT1, USGS.HT1, as well as WWF.HT1, have global coverage, while the rest extend across Europe. However, for the European datasets, as observed in

Figure 8, there are some spatial inconsistencies among the datasets, even in cases where they are contained in the same data repository. Specifically, although the entire Turkey, western Balkans, and Norway are considered in the dataset High Nature Farmland (EEAD.HT1) and Natural Assemblage Tree Species Indicator (EEAD.HT4), these countries have not been included in the dataset Richness of Forest-related Species and Habitats Indicator (EEAD.HT). Finally, the spatial resolution of the raster datasets can be characterized as more than satisfactory, considering their pan-European (or in some cases, global) coverage, where the coarser dataset is provided with a 1km cell size.

Table 13. Datasets included in the catalogue related to terrestrial habitat.

Index	Data repository	Data short description	Reference
EEAD.HT1	EEAD	High nature farmland	Schwaiger et al. 2012 EEA
EEAD.HT2		Linkages of species and habitat types to MAES ecosystems	Roscher et al. 2015 ETC/BD EEA
EEAD.HT3		Linkages of species and habitat types to MAES ecosystems	Roscher et al. 2015 ETC/BD EEA
EEAD.HT4		Natural assemblage tree species indicator	EEA
EEAD.HT5		Richness of forest-related species and habitats indicator	EEA
UoM.FCC.HT1	UoM	Forest Cover Change	Hensen et al. 2013 Science
USGS.HT1	USGS	The World Terrestrial Ecosystems	USGS
TreeAtlas.HT1	TreeAtlas	The European Atlas of Forest Tree Species: Maximum Habitat Suitability	Mauri et al. 2016 Pub. Office of EU
WWF.HT1	WWF	Terrestrial Ecoregions of the World	Olson et al. 2001 Bioscience

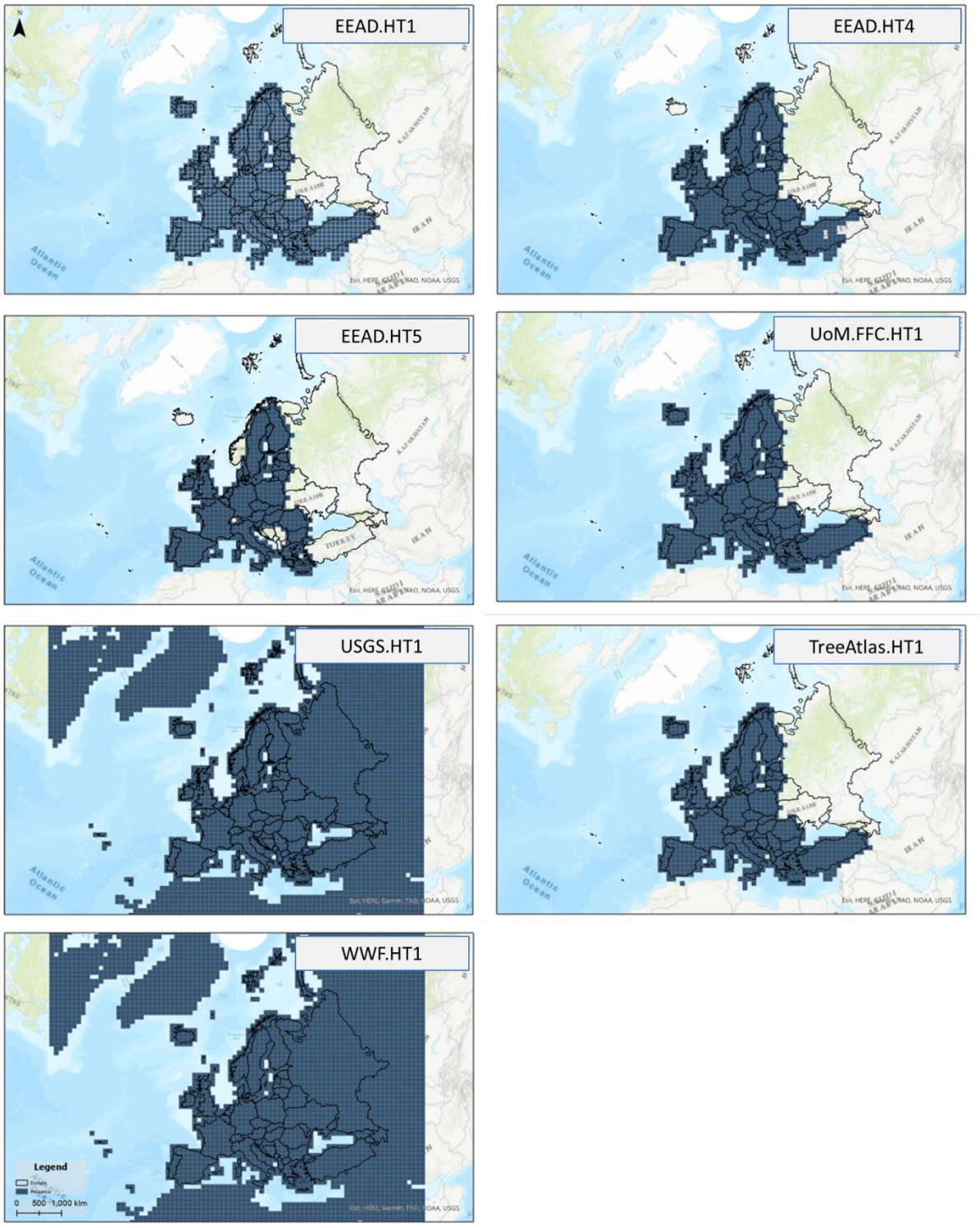
Source: this report.

Table 14. Spatial characteristics for the datasets related to terrestrial habitat.

Index	Basis of record	Spatial format	File format	Coverage	Projection	Spatial resolution
EEAD.HT1	Modelling	Raster	GeoTIFF	European	WGS 1984	100m
EEAD.HT2	Expert observation	No-spatial data	Access/CVS	European		
EEAD.HT3	Expert observation	No-spatial data	Access/CVS	European		
EEAD.HT4	Modelling	Raster	GeoTIFF	Global	WGS 1984	1km
EEAD.HT5	Modelling	Raster	GeoTIFF	Global	WGS 1984	1km
UoM.FCC.HT1	Modelling	Raster	GeoTIFF	Global	WGS 1984	30m
USGS.HT1	Modelling	Raster	GeoTIFF	Global	WGS 1984	250m
TreeAtlas.HT1	Modelling	Raster	GeoTIFF	European	ETRS 1989	1km
WWF.HT1	Modelling	Polygon	Shapefile	Global	WGS 1984	Unspecified

Source: this report.

Figure 8. Available datasets related to terrestrial habitats.



Source: this report.

3.2.3 Habitats: Multiple

Datasets that have been indicated as multiple represent habitats (or species) that cover both marine, terrestrial, or transitional ecosystems. Considering the above characterization, 11 datasets have been included in the catalogue for this habitat category, retrieved from EEA and UNEP-WCMC

(Tables 15 & 16 and Figure 9). Starting with the datasets provided by UNEP-WCMC, three of them focus on mangroves, a habitat that is not distributed in Europe. Additionally, one dataset indicates the level of criticality in habitats, have been assessed and integrated into the catalogue. As for the selected datasets from EEA, all of them are ready to be utilized for habitat mapping purposes. Specifically, these datasets are a) the spatial layer of habitats included in Article 17 (EEAD. HMu1), b) the spatial layers of habitat according to EUNIS (EEAD.HMu2), and c) a layer indicating the extended wetland ecosystems (EEAD.HMu3). In the catalogue, 3 non-spatial datasets acquired from EEAD, which link species and habitats to MAES typologies, have also been included. Although the spatial information is missing, the datasets provide the descriptions that can be used for georeferencing.

Regarding the basis of record, the datasets can be categorized into two groups: a) the indicators that were calculated via modelling procedures, and b) the observations, which are the results of field works taken place by experts. As a result, the spatial format of the datasets are raster for the indicators (i.e., EEAD.HMu3 and UNEP.WCMC.HMu1), while the rest are in polygon format. The spatial distribution of the datasets varies among the data repositories, as EEA's data extend across Europe, with a particular focus on countries that have the obligation to map and monitor their habitats (Article 17). On the other hand, UNEP-WCMC's datasets, in most cases, are species-oriented and therefore focus on areas with specific needs. This was the case in the selected datasets, where a type of habitat that is not distributed in Europe is mapped (Figure 9).

Table 15. Datasets included in the catalogue related to both marine and terrestrial habitat.

Index	Data repository	Data short description	Reference
EEAD.HMu1	EEAD	Conservation status of habitat types from Article 17	EEA
EEAD.HMu2		EUNIS habitat classification	Davies et al. 2004 EEA
EEAD.HMu3		Extended wetland ecosystem layer	Maes et al. 2020 Pub. Office of EU
EEAD.HMu4		Linkages of species and habitat types to MAES ecosystems	Roscher et al. 2015 ETC/BD EEA
EEAD.HMu5		Linkages of species and habitat types to MAES ecosystems (Association birds and MAES typologies at EU level)	Roscher et al. 2015 ETC/BD EEA
EEAD.HMu6		Linkages of species and habitat types to MAES ecosystems	Roscher et al. 2015 ETC/BD EEA
EEAD.HMu7		Linkages of species and habitat types to MAES ecosystems (Association non-bird species and MAES typologies at regional level)	Roscher et al. 2015 ETC/BD EEA
UNEP.WCMC.HMu1	UNEP.WCMC	Global Critical Habitat Screening Layer	UNEP-WCMC 2017, Brauneder et al. 2018 Plos One, Martin et al. 2015 Mar. Pol.
UNEP.WCMC.HMu2		Global biophysical typology of mangroves	Worthington et al. 2020 Scie. Rep.
UNEP.WCMC.HMu3		World Atlas of Mangroves	Spalding et al. 2010 ITTO, ISME, FAO, UNEP-WCMC, UNESCO-MAB, UNU-INWEH and TNC

UNEP.WCMC.HMu4		Global Mangrove Watch	Bunting et al. 2018 Rem. Sen., Thomas et al. 2017 Plos One

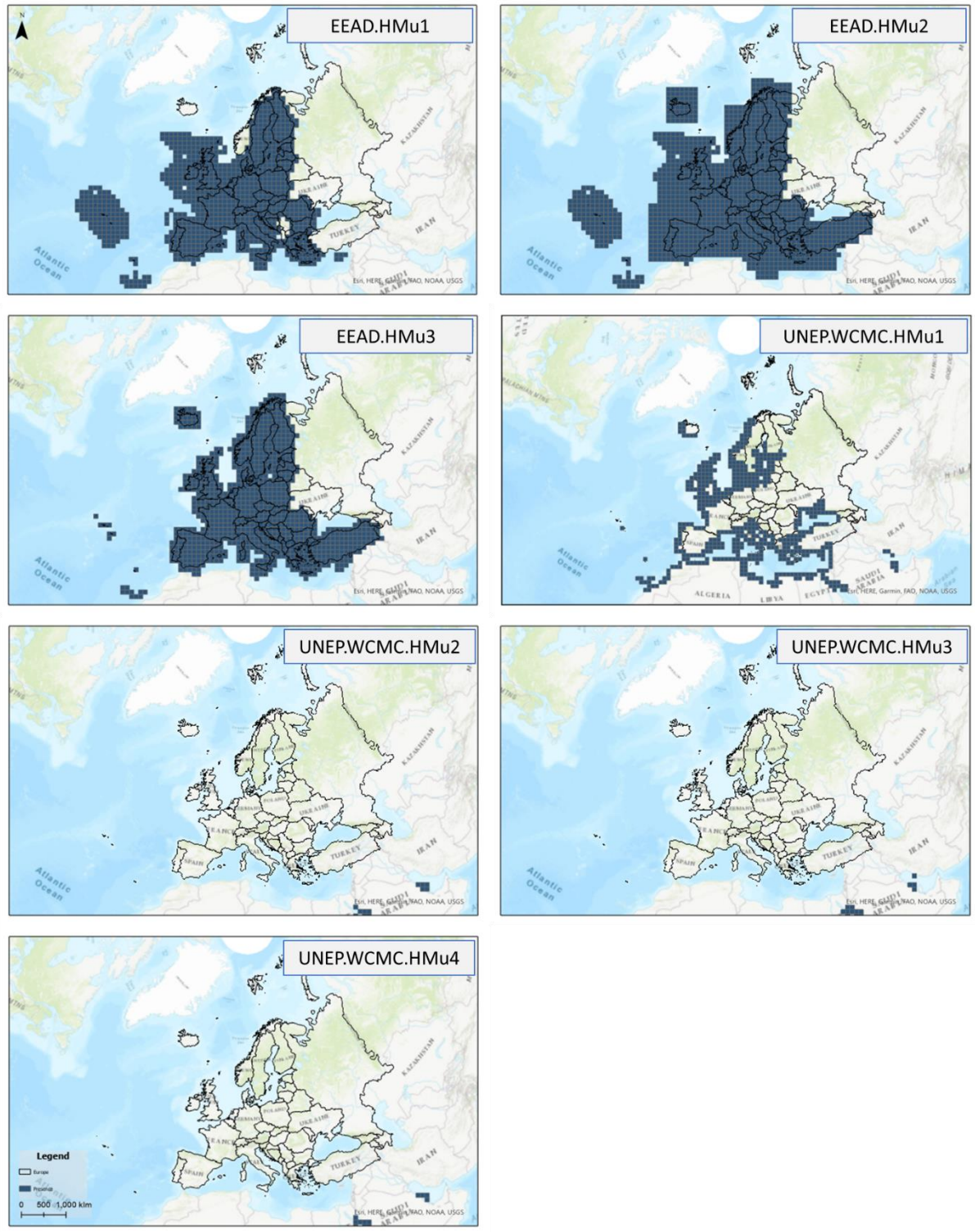
Source: this report.

Table 16. Spatial characteristics for the datasets related to both marine and terrestrial habitat.

Index	Basis of record	Spatial format	File format	Coverage	Projection	Spatial resolution
EEAD.HMu1	Expert observation	Polygon	Shapefile	European	ETRS 1989	Unspecified
EEAD.HMu2	Expert observation	Polygon	Shapefile	European	ETRS 1989	Unspecified
EEAD.HMu3	Modelling	Raster	GeoTIFF	European	ETRS 1989	Unspecified
EEAD.HMu4	Expert observation	No-spatial data	Access/CVS	European		
EEAD.HMu5	Expert observation	No-spatial data	Access/CVS	European		
EEAD.HMu6	Expert observation	No-spatial data	Access/CVS	European		
EEAD.HMu7	Expert observation	No-spatial data	Access/CVS	European		
UNEP.WCMC.HMu1	Modelling	Raster	GeoTIFF	Global	WGS 1984	1km
UNEP.WCMC.HMu2	Machine observation	Polygon	Shapefile	Global	WGS 1984	Unspecified
UNEP.WCMC.HMu3	Machine observation	Polygon	Shapefile	Global	WGS 1984	Unspecified
UNEP.WCMC.HMu4	Machine observation	Polygon	Shapefile	Global	WGS 1984	Unspecified

Source: this report.

Figure 9. Available datasets related to both marine and terrestrial habitats.



Source: this report.

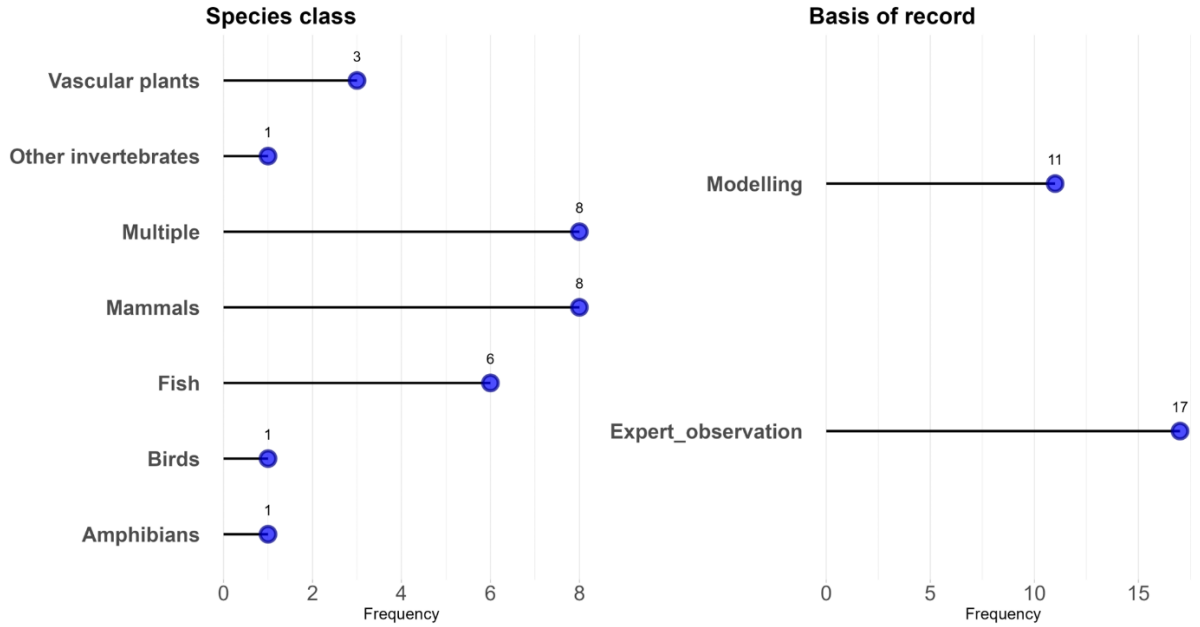
3.2.4 Species: Marine

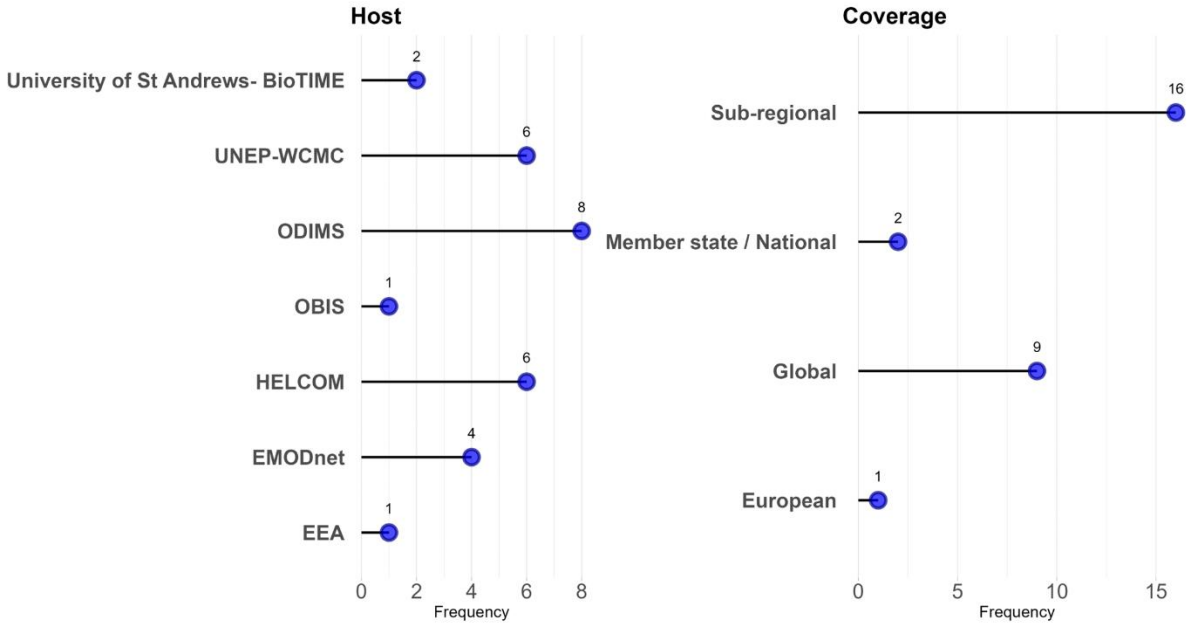
At the species level, marine species dominate the catalogue, with 28 data included (Tables 17 & 18, Figures 10-15). Marine mammals, followed by fish, have the highest number of entries in the catalogue, with 8 and 6 datasets, respectively. Vascular plants are represented by 3 datasets, while

reptiles, birds, other invertebrates, and amphibians are each represented by 1 dataset. Additionally, there are 8 datasets that integrate information from various marine species. As for the basis of record 17 datasets were obtained through expert observations, while the remaining 11 were derived from modelling procedures. The main providers of this data were ODIMS, UNEP-WCMC, and HELCOM, with 8 datasets for the first one and 6 datasets for the other two. On the contrary, although EEA and OBIS are the data repositories with the fewest direct references to marine species, their datasets contains a wide range of species belonging to various taxa (Figure 10).

Regarding spatial distribution, 16 datasets are on a sub-regional scale, while 9 are on a global scale. Specifically, when examining the spatial distribution of species datasets (as observed in Figures 11-15), the datasets referring to mammals focus exclusively on the European part of the Atlantic Ocean or the North Sea (Figure 11). For fish taxa, there are no datasets acquired in the Mediterranean Sea, as all available datasets derived from OSPAR and HELCOM are retrieved for the Atlantic Ocean and the Northern Sea (Figure 12). Regarding vascular plants, the datasets examine the distribution of seagrasses and kelps, covering all well-known areas where these species are distributed (Figure 13). However, there is a lack of datasets for other taxa. For example, there are no available datasets related to reptiles in any European sea or the European part of Atlantic Ocean. In addition, in the Mediterranean, there is no dataset available for amphibians, other invertebrates, and birds (Figure 14). One notable data repository that provides datasets across European seas is OBIS, which presents the distribution of multiple marine species. The spatial distribution of the remaining datasets is focused on the examined species or the regions under the consideration of the supervising organization (Figure 15).

Figure 10. Main characteristics of considered datasets for marine species.





Source: this report.

Table 17. Datasets included in the catalogue related to marine species.

Index	Data description	Species class	Reference
EEAD.SM1	Marine non-indigeous species	Fish	EEA
OBIS.SM1	World ocean biodiversity and biogeographic data	Multiple	OBIS
OSPAR.SM1	Abundance and Distribution of Coastal Bottlenose	Mammals	OSPAR Commission
OSPAR.SM2	Abundance and Distribution of Fin Whale	Mammals	OSPAR Commission
OSPAR.SM3	Abundance and Distribution of Minke Whale	Mammals	OSPAR Commission
OSPAR.SM4	Abundance and Distribution of Offshore Bottlenose	Mammals	OSPAR Commission
OSPAR.SM5	Abundance and Distribution of White Beaked Dolphin	Mammals	OSPAR Commission
OSPAR.SM6	Recovery of sensitive fish species (Scyliorhinus Stellaris)	Fish	OSPAR Commission
OSPAR.SM7	Recovery of sensitive fish species (Torpedo Marmorata)	Fish	OSPAR Commission
OSPAR.SM8	Recovery of sensitive fish species (Lophius Piscatorius)	Fish	OSPAR Commission
UNEP.WCMC.SM1	Global Distribution of Cold-water Corals	Multiple	Freiwald et al. 2021 UNEP-WCMC, Freiwald et al. 2004 UNEP-WCMC
UNEP.WCMC.SM2	Global Distribution of Seagrasses	Vascular plants	UNEP-WCMC & Short 2003 UNEP-WCMC, Green & Short 2003 Uni. Cal. Press, Belluscio et al. 2013 HCMR, Telesca et al. 2015 Scie. Rep., OSPAR Commission 2015 OSPAR

UNEP.WCMC.SM3	Modelled Global Distribution of the Kelp Biome	Vascular plants	Jayathilake & Costello 2020 Biol. Cons.
UNEP.WCMC.SM4	Global Distributions of Cold-Water Octocorals	Multiple	Yesson et al. 2012 Journal of Bioge.
UNEP.WCMC.SM5	Global Seagrass Species Richness	Vascular plants	Green & Short 2003 Uni. Of California
UNEP.WCMC.SM6	Global Patterns of Marine Biodiversity	Multiple	Tittensor et al. 2010 Nature
BioTIME.SM1	Global database of assemblage time series for quantifying and understanding biodiversity change	Amphibians	Dornelas et al. 2018 Global Ecol. Bioge.
BioTIME.SM2	Global database of assemblage time series for quantifying and understanding biodiversity change	Other invertebrates	Dornelas et al. 2018 Global Ecol. Bioge.
EmodNET.SM1	EMODnet-Biology-fraction-mixoplankton-Greater-North-Sea	Multiple	Willem Stolte & Lisa Schneider 2020 EMODnet
EmodNET.SM2	Grey Seal Distribution	Mammals	National Parks and Wildlife Service
EmodNET.SM3	Harbour Seal Distribution	Mammals	National Parks and Wildlife Service
EmodNET.SM4	Presence-absence benthos in the European Seas	Multiple	Hermam 2022 EMODnet
HELCOM.SM1	Ecosystem Components BSII	Multiple	HELCOM
HELCOM.SM2	Breading and Wintering areas for birds	Birds	HELCOM HOLAS 3 Dataset 2023
HELCOM.SM3	Fish BSII (Cod, Herring, Sprat)	Fish	HELCOM
HELCOM.SM4	Fish BSII (Harbour porpoise, Grey seal, Harbour seal, Ringed seal)	Mammals	HELCOM
HELCOM.SM5	Essential fish habitat maps PBS	Fish	HELCOM
HELCOM.SM6	Red list of species and habitats	Multiple	IUCN/Multiple

Source: this report.

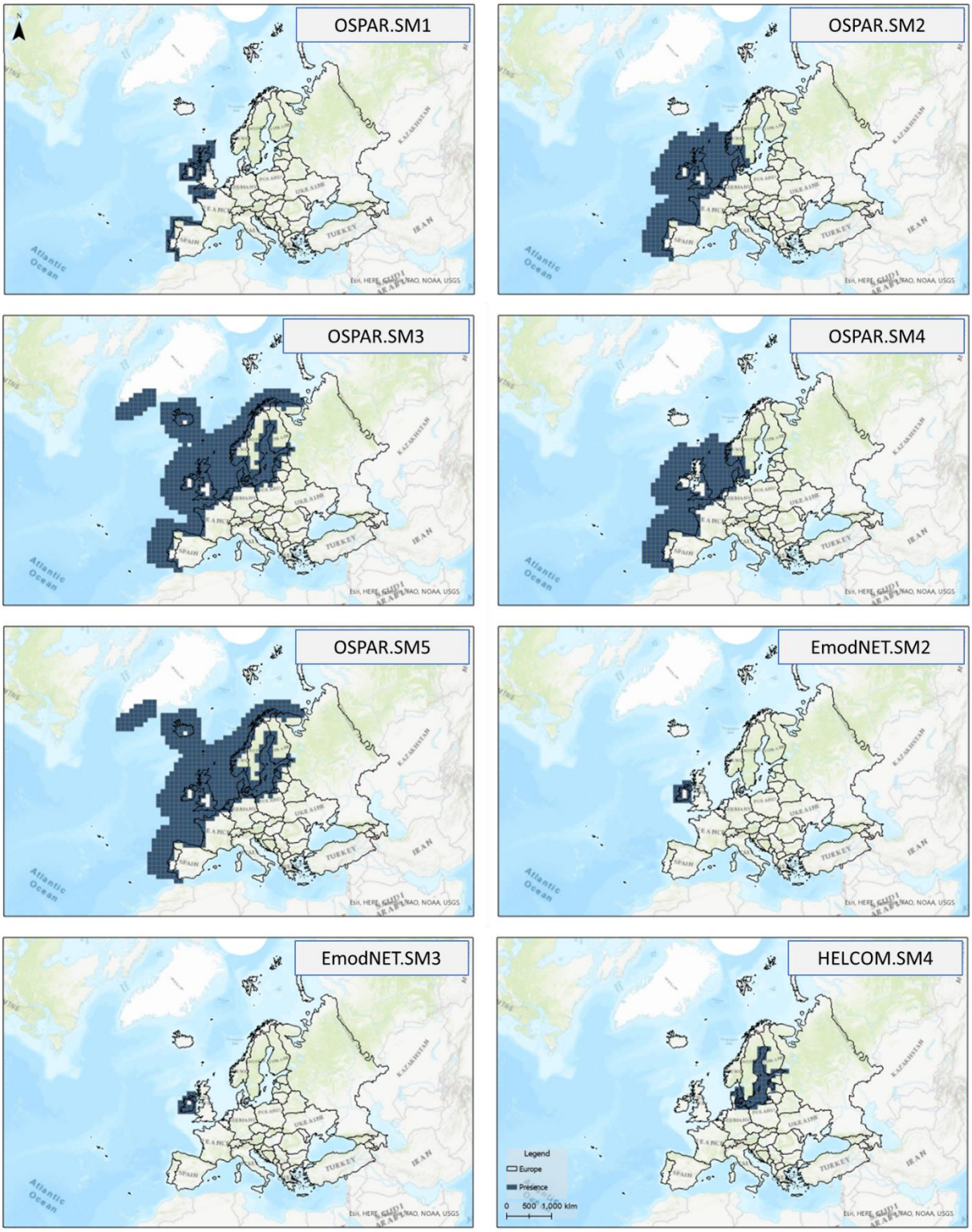
Table 18. Spatial characteristics for the datasets related to marine species.

Index	Basis of record	Spatial format	File format	Coverage	Projection	Spatial resolution
EEAD.SM1	Expert observation	No-spatial data	xls	Sub-regional		
OBIS.SM1	Expert observation	Multiple	Multiple	Global	WGS 1984	Unspecified
OSPAR.SM1	Expert observation	Polygon	Shapefile	Sub-regional	WGS 1984	Unspecified
OSPAR.SM2	Expert observation	Polygon	Shapefile	Sub-regional	WGS 1984	Unspecified
OSPAR.SM3	Expert observation	Polygon	Shapefile	Sub-regional	WGS 1984	Unspecified
OSPAR.SM4	Expert observation	Polygon	Shapefile	Sub-regional	WGS 1984	Unspecified
OSPAR.SM5	Expert observation	Polygon	Shapefile	Sub-regional	WGS 1984	Unspecified
OSPAR.SM6	Expert observation	Polygon	Shapefile	Sub-regional	WGS 1984	Unspecified

OSPAR.SM7	Expert observation	Polygon	Shapefile	Sub-regional	WGS 1984	Unspecified
OSPAR.SM8	Expert observation	Polygon	Shapefile	Sub-regional	WGS 1984	Unspecified
UNEP.WCMC.SM1	Expert observation	Multiple	Shapefile	Global	WGS 1984	Unspecified
UNEP.WCMC.SM2	Expert observation	Multiple	Shapefile	Global	WGS 1984	Unspecified
UNEP.WCMC.SM3	Modelling	Polygon	Shapefile	Global	WGS 1984	Unspecified
UNEP.WCMC.SM4	Modelling	Raster	GeoTIFF	Global	WGS 1984	~18km
UNEP.WCMC.SM5	Modelling	Polygon	Shapefile	Global	WGS 1984	Unspecified
UNEP.WCMC.SM6	Modelling	Polygon	Shapefile	Global	WGS 1984	Unspecified
BioTIME.SM1	Expert observation	Point	Shapefile	Global	WGS 1984	Unspecified
BioTIME.SM2	Expert observation	Point	Shapefile	Global	WGS 1984	Unspecified
EmodNET.SM1	Modelling	Raster	GeoTIFF	Sub-regional	WGS 1984	~50km
EmodNET.SM2	Expert observation	Polygon	Shapefile	Member state / National	WGS 1984	10 km
EmodNET.SM3	Expert observation	Polygon	Shapefile	Member state / National	WGS 1984	10 km
EmodNET.SM4	Expert observation	Point	Shapefile	European	WGS 1984	Unspecified
HELCOM.SM1	Modelling	Raster	WMS	Sub-regional	WGS 1984	1km
HELCOM.SM2	Modelling	Raster	WMS	Sub-regional	WGS 1984	1km
HELCOM.SM3	Modelling	Raster	WMS	Sub-regional	WGS 1984	1km
HELCOM.SM4	Modelling	Raster	WMS	Sub-regional	WGS 1984	1km
HELCOM.SM5	Modelling	Raster	WMS	Sub-regional	WGS 1984	1km
HELCOM.SM6	Modelling	Raster	WMS	Sub-regional	WGS 1984	1km

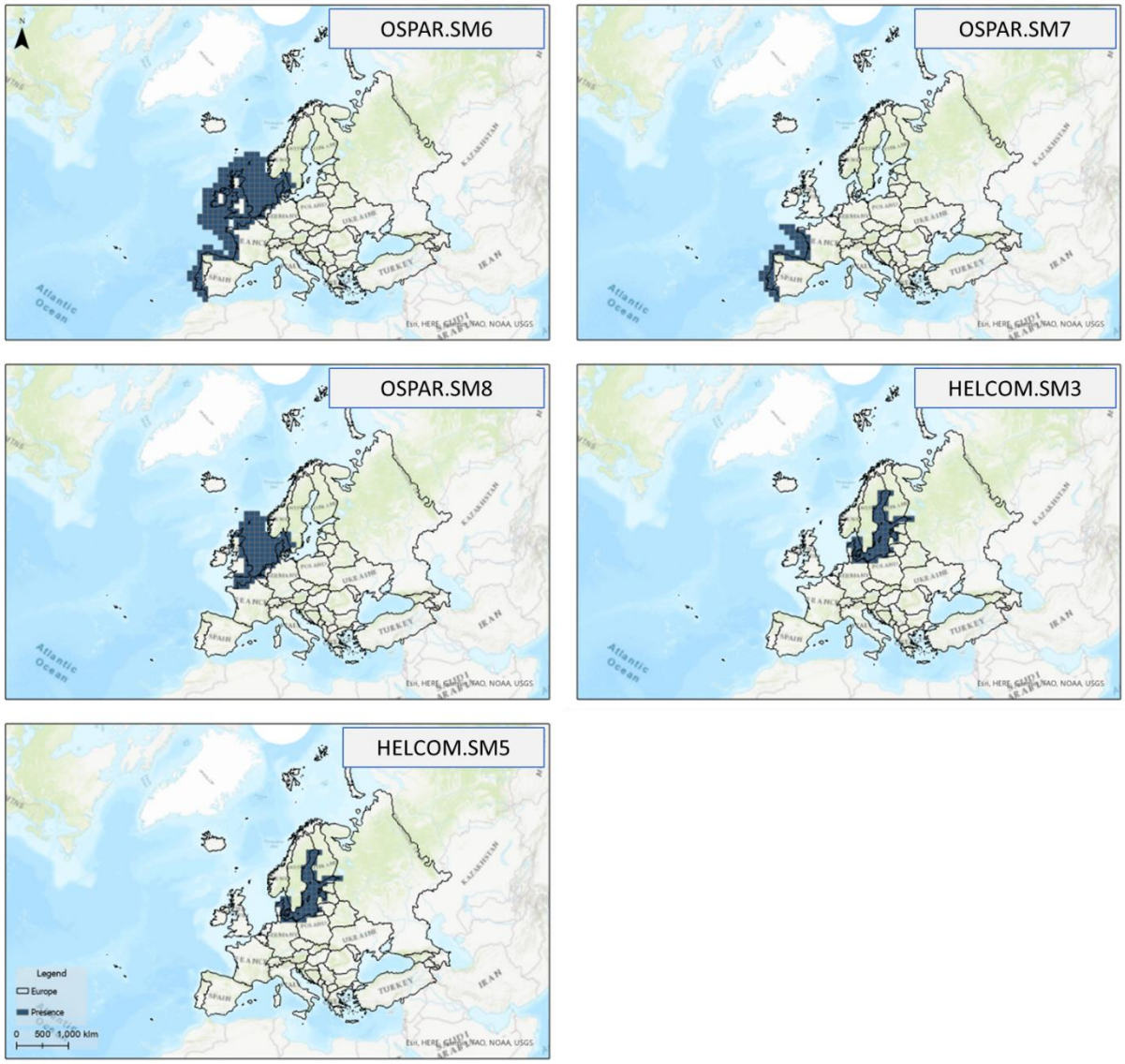
Source: this report.

Figure 11. Spatial coverage of datasets related to marine mammals based on different datasets.



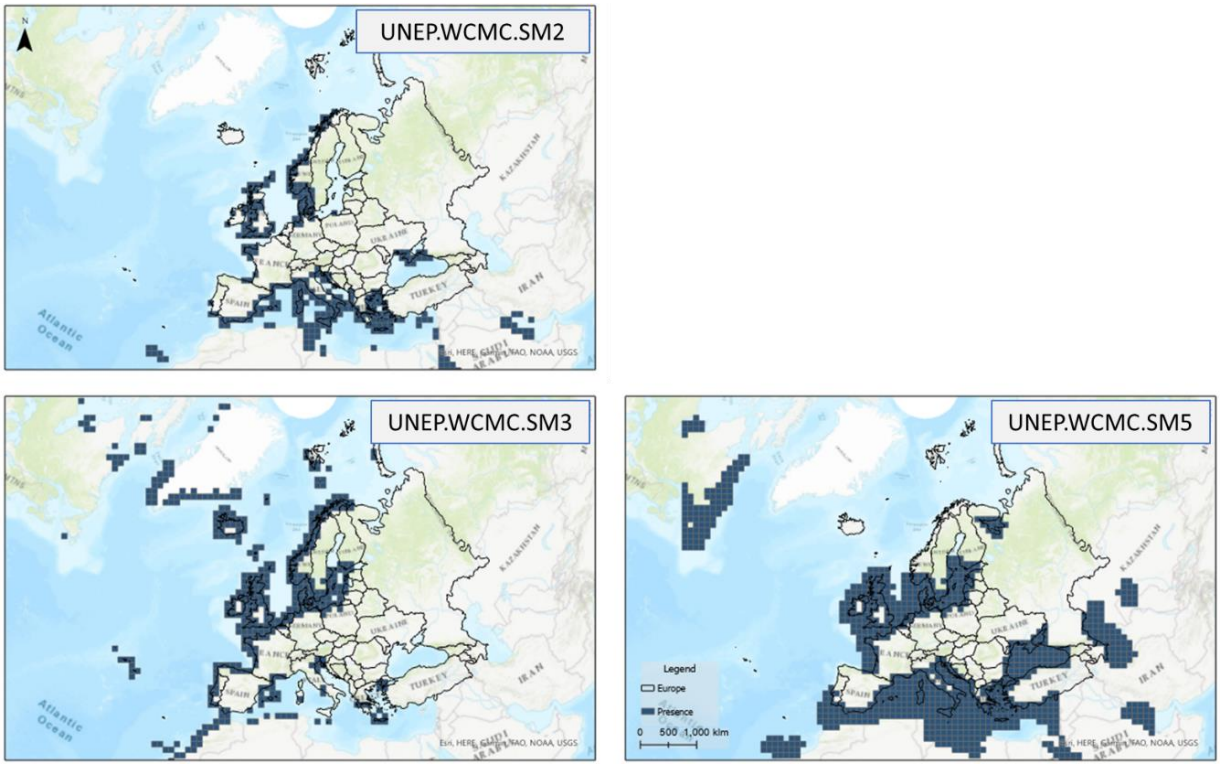
Source: this report.

Figure 12. Available datasets related to fish (marine species).



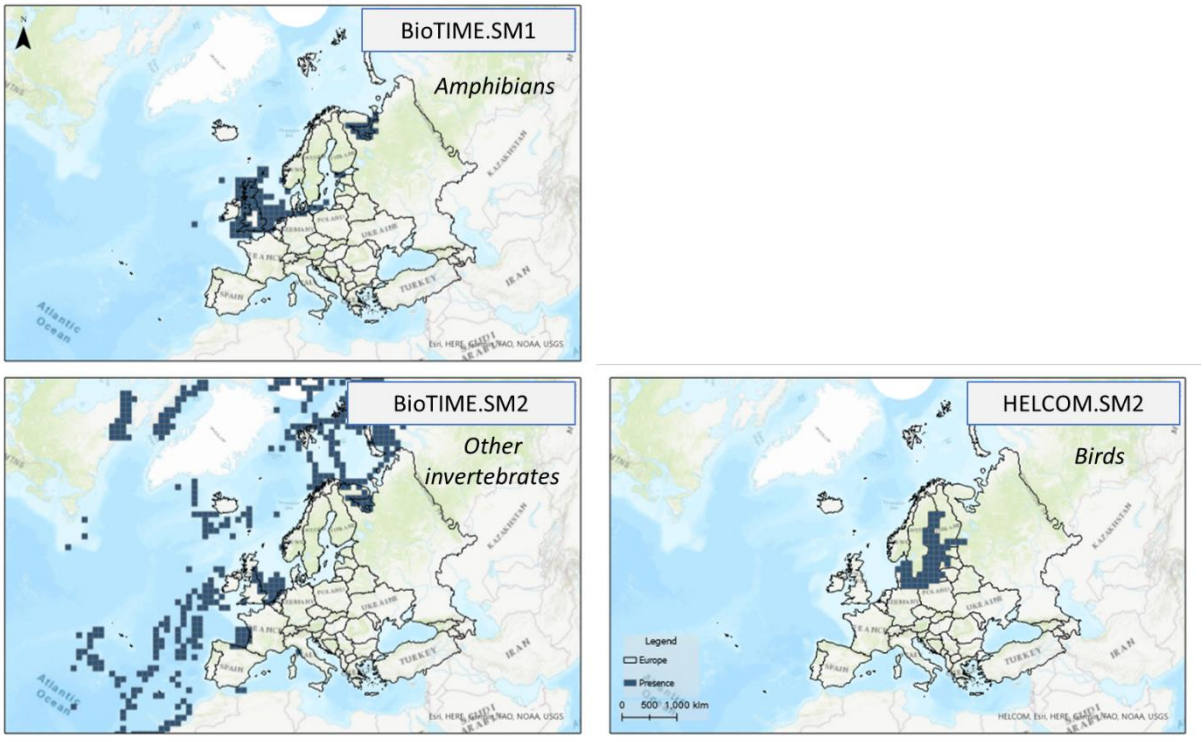
Source: this report.

Figure 13. Available datasets related to marine vascular plants.



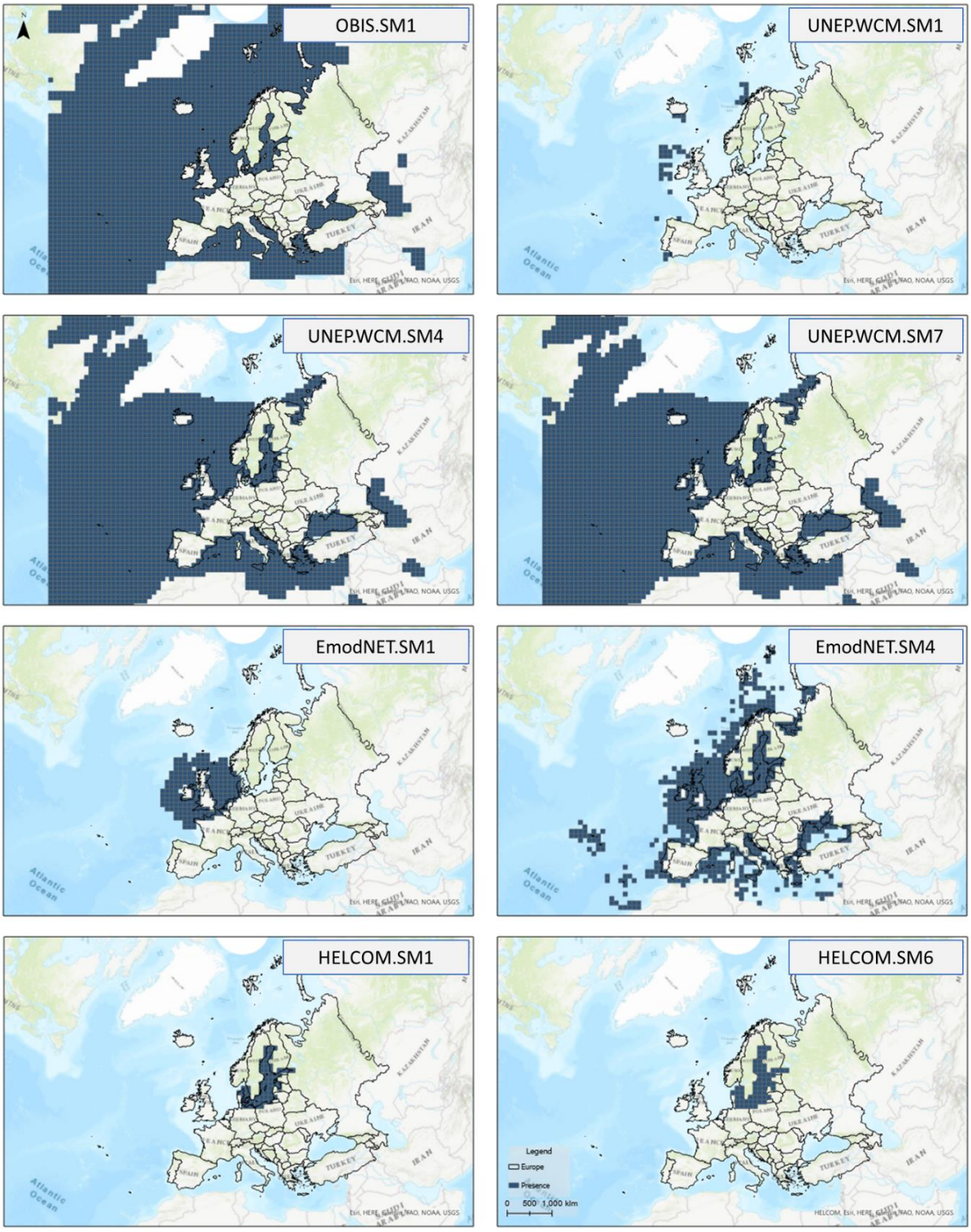
Source: this report.

Figure 14. Available datasets related to marine amphibians, other invertebrates, and birds.



Source: this report.

Figure 15. Available datasets multiple marine taxa.



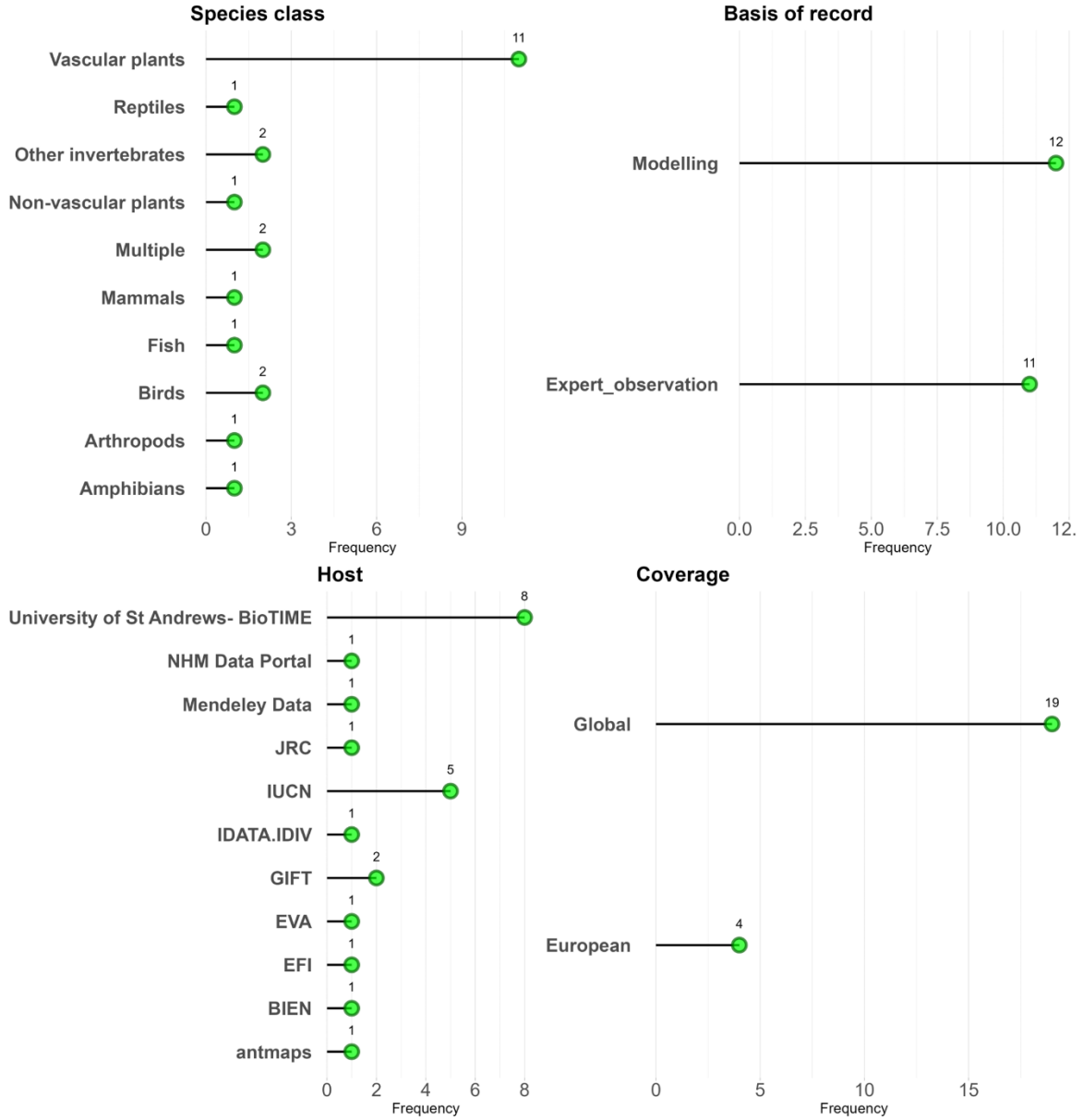
Source: this report.

3.2.5 Species: Terrestrial & Freshwater

The datasets considered and integrated into the catalogue for terrestrial and freshwater habitats are given in Tables 19 and 20, as well as presented in Figures 16-18. The majority of the datasets represent vascular plants (11 data), while the remaining taxa are represented by 2 or 1 datasets each. Modelling techniques is the main method used for recording data, with 12 datasets were estimated through this procedure, while 11 datasets acquired through expert observations (Figure 16 and Table 20).

In contrast to species datasets related to marine ecosystems, the selected datasets for terrestrial species cover the Europe or have global coverage (Figure 16 and Table 20). The main providers of these datasets are IUCN and BioTime, which are datasets sources with historical records of various flora and fauna species across the world. Regarding the coverage of terrestrial species datasets, all data related to vascular plants cover the entire Europe, with the exception of datasets retrieved by BioTime, which cover only two regions in central Europe. BioTime repository appears to lack datasets for other taxa such, non-vascular plants, birds, invertebrates, and freshwater fish, as they seem to be misrepresented across Europe. On the contrary, datasets delivered by IUCN appears to be more complete, covering all of the Europe (Figures 17 & 18).

Figure 16. Main characteristics of considered datasets for terrestrial and freshwater species.



Source: this report.

Table 19. Datasets included in the catalogue related to terrestrial and freshwater species.

Index	Data description	Species class	Reference
BIEN.ST1	Observations of individuals and species from specimens and vegetation inventories	Vascular plants	BIEN
EVA.ST1	European Vegetation Survey	Vascular plants	Chytrý et al.2016 Applied Veg. Science
GABI.ST1	Compile all known information on the geographic distribution of all ant species	Arthropods	Guénard et al. 2017 Myrmecological News
GIFT.ST1	Global Inventory of Floras and Traits - Species richness	Vascular plants	Cai et al. 2023 New Phytologist

GIFT.ST2	Global Inventory of Floras and Traits - Phylogenetic richness	Vascular plants	Cai et al. 2023 New Phytologist
IUCN.ST1	The IUCN Red List of Threatened Species	Mammals	IUCN
IUCN.ST2		Amphibians	IUCN
IUCN.ST3		Birds	IUCN
IUCN.ST4		Vascular plants	IUCN
IUCN.ST5		Multiple	IUCN
NHM.BTE.ST1	Global map of the Biodiversity Intactness Index	Multiple	Newbold et al. (2016) Science
VASC.ST1	Global patterns of vascular plant alpha diversity	Vascular plants	Sabatini et al. 2022 Nature Com.
BioTIME.ST1	BioTime	Birds	Dornelas et al. 2018 Global Ecol. Bioge.
BioTIME.ST2		Other invertebrates	Dornelas et al. 2018 Global Ecol. Bioge.
BioTIME.ST3		Vascular plants	Dornelas et al. 2018 Global Ecol. Bioge.
BioTIME.ST4		Non-vascular plants	Dornelas et al. 2018 Global Ecol. Bioge.
BioTIME.ST5		Reptiles	Dornelas et al. 2018 Global Ecol. Bioge.
BioTIME.ST6		Other invertebrates	Dornelas et al. 2018 Global Ecol. Bioge.
BioTIME.ST7		Vascular plants	Dornelas et al. 2018 Global Ecol. Bioge.
BioTIME.ST8		Fish	Dornelas et al. 2018 Global Ecol. Bioge.
EWS.ST1	Chorological data for the main European woody species	Vascular plants	Caudullo et al. 2022 Mendeley Data
EFI.ST1	Tree species maps for European forests	Vascular plants	Brus et al. 2011 Eu Jou.of For.Resea., Hengeveld et al. 2011 Ecol. & Soci., Nabuurs 2009 Alte. & Euro Fore. Insti., Shuck et al. 2002 Eur. Fore. Insti., Troltzsch et al. 2009 Fore. Ecol & Mana.
TreeAtlas.ST1	The European Atlas of Forest Tree Species: Relative Probability of Presence	Vascular plants	Mauri et al. 2016 Pub. Office of EU

Source: this report.

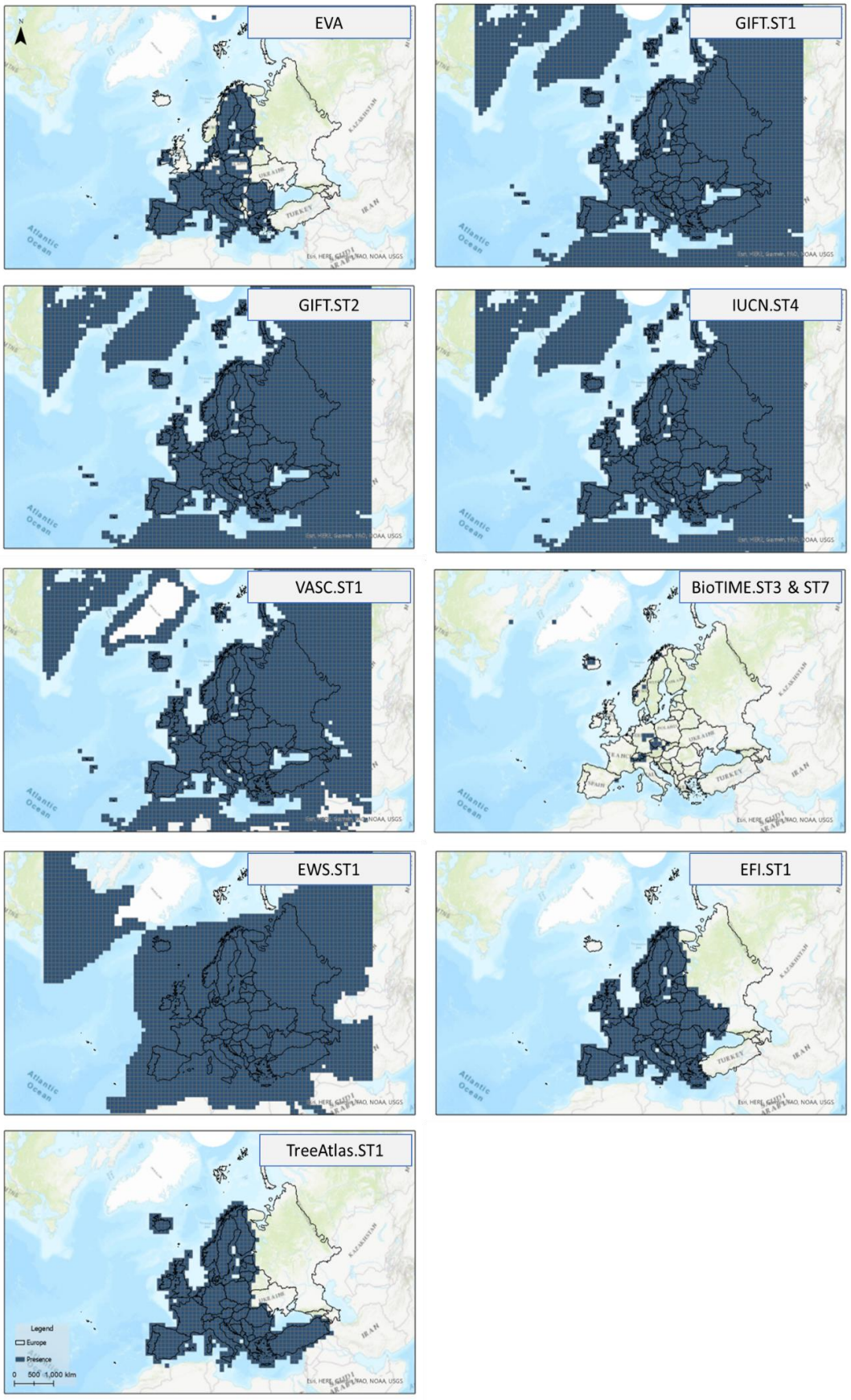
Table 20. Spatial characteristics for the datasets related to terrestrial and freshwater species.

Index	Basis of record	Spatial format	File format	Coverage	Projection	Spatial resolution
BIEN.ST1	Expert observation	Polygon	Shapefile	Global	WGS 1984	Unspecified
EVA.ST1	Expert observation	Table	CVS	European	WGS 1984	Unspecified
GABI.ST1	Expert observation	Polygon	Shapefile	Global	WGS 1984	Country
GIFT.ST1	Modelling	Multiple	Shapefile	Global	WGS 1984	100 km hexagons

GIFT.ST2	Modelling	Multiple	Shapefile	Global	WGS 1984	100 km hexagons
IUCN.ST1	Modelling	Polygon	Shapefile	Global	WGS 1984	Unspecified
IUCN.ST2	Modelling	Polygon	Shapefile	Global	WGS 1984	Unspecified
IUCN.ST3	Modelling	Polygon	Shapefile	Global	WGS 1984	Unspecified
IUCN.ST4	Modelling	Polygon	Shapefile	Global	WGS 1984	Unspecified
IUCN.ST5	Modelling	Polygon	Shapefile	Global	WGS 1984	Unspecified
NHM.BTE.ST1	Modelling	Raster	ASCII	Global	WGS 1984	1km
VASC.ST1	Modelling	Raster	GeoTIFF	Global	WGS 1984	1 km
BioTIME.ST1	Expert observation	Point	Shapefile	Global	WGS 1984	Unspecified
BioTIME.ST2	Expert observation	Point	Shapefile	Global	WGS 1984	Unspecified
BioTIME.ST3	Expert observation	Point	Shapefile	Global	WGS 1984	Unspecified
BioTIME.ST4	Expert observation	Point	Shapefile	Global	WGS 1984	Unspecified
BioTIME.ST5	Expert observation	Point	Shapefile	Global	WGS 1984	Unspecified
BioTIME.ST6	Expert observation	Point	Shapefile	Global	WGS 1984	Unspecified
BioTIME.ST7	Expert observation	Point	Shapefile	Global	WGS 1984	Unspecified
BioTIME.ST8	Expert observation	Point	Shapefile	Global	WGS 1984	Unspecified
EWS.ST1	Modelling	Multiple	Shapefile	European	WGS 1984	Unspecified
EFI.ST1	Modelling	Raster	GeoTIFF	European	ETRS 1989	Unspecified
TreeAtlas.ST1	Modelling	Raster	GeoTIFF	European	ETRS 1989	1km

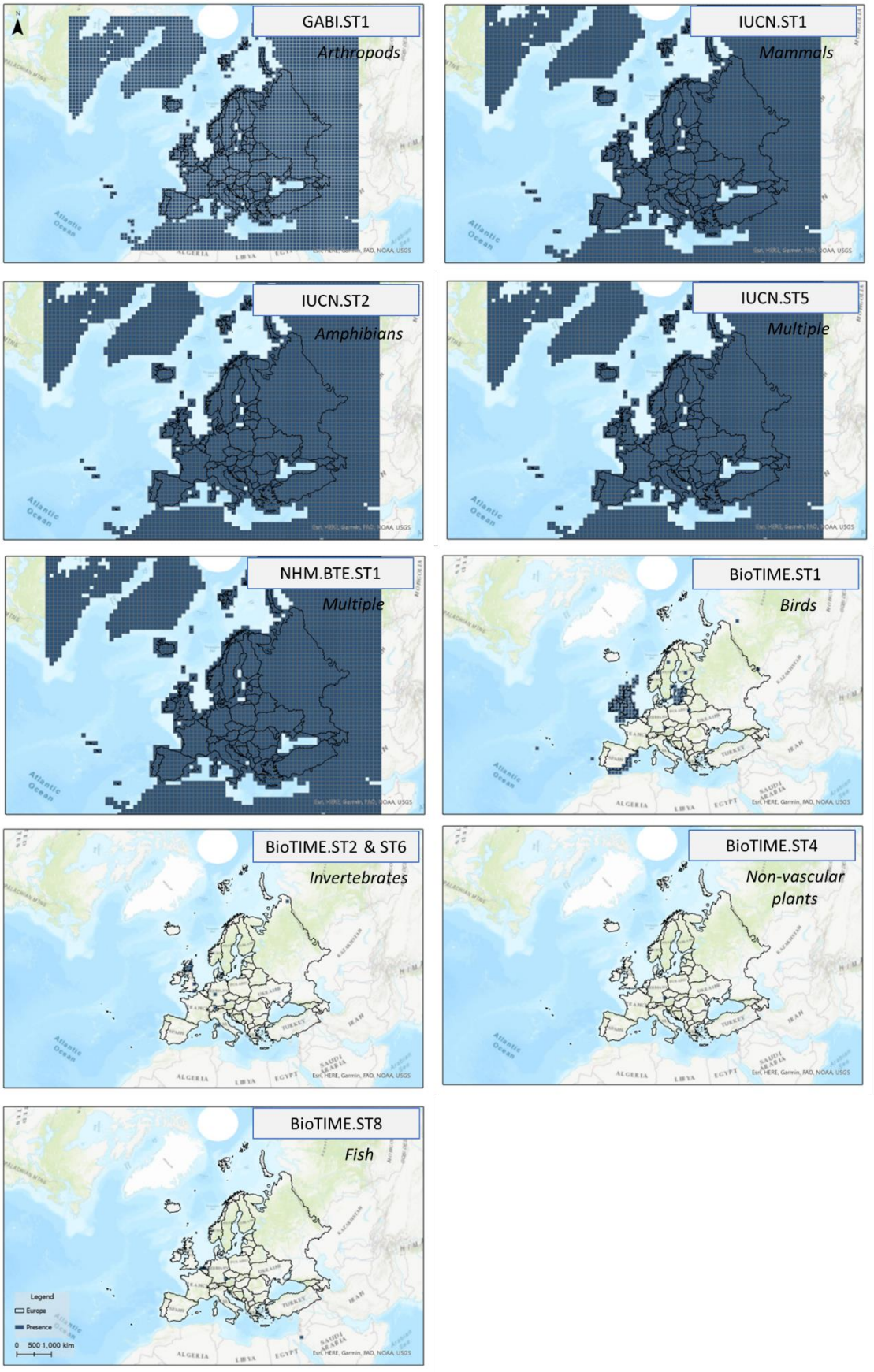
Source: this report

Figure 17. Available datasets related to terrestrial and freshwater vascular plants.



Source: this report.

Figure 18. Available datasets related to terrestrial and freshwater.



Source: this report.

3.2.6 Species: Multiple

The catalogue includes species datasets that cover both marine and terrestrial ecosystems simultaneously. There are 11 datasets in total (Tables 21 and 22, Figure 19). Among these datasets, the most significant ones are those provided under Articles 17 and 12, which cover various taxa and bird species, respectively, and updated regularly by all member states. Bird species are also represented in the catalogue through datasets provided by OSPAR, which indicate the areas where various bird species occur. Additionally, multiple dataset points have been marked as integrating records from various taxa or being formed as indicators, such as the data for LPI.SMu1 or IUCN.SMu1. It is worth noting that the majority of the selected datasets have been formed through expert observation. In terms of datasets coverage, LPI provides a complete and comprehensive dataset covering the entire Europe. OSPAR-derived datasets focus on the European Atlantic Ocean part and the North Sea, while datasets retrieved by EEA cover all European countries, especially those with a legal obligation to monitor and protect their habitats and species under the framework of Articles 12 and 17.

Table 21. Datasets included in the catalogue related to both marine and terrestrial species.

Index	Data description	Species class	Reference
BRDI.SMu1	BirdLife's species distribution data	Birds	Birdlife International
EEAD.SMu1	Conservation status of species from Article 17	Multiple	EEA
EEAD.SMu2	Status and trends of bird populations datasets from Article 12	Birds	EEA
EEAD.SMu3	Invasive Alien Species reporting under EU Regulation	Multiple	DG ENV - EEA
IUCN.SMu1	The IUCN Red List of Threatened Species	Multiple	IUCN
IUCN.SMu2		Reptiles	IUCN
OSPAR.SMu1	Marine Birds - Non-breeding Abundance - Colonies and Sites	Birds	OSPAR Commission
OSPAR.SMu2	Marine Birds Breeding Abundance - Breeding colonies and sites for assessment	Birds	OSPAR Commission
OSPAR.SMu3	Marine Birds Breeding Productivity - Breeding colonies and sites for assessment	Birds	OSPAR Commission
LPI.SMu1	A measure of the state of the world's biological diversity based on population trends of vertebrate species from terrestrial, freshwater and marine habitats.	Multiple	WWF-ZSL
BioTIME.SMu1	Global database for quantifying biodiversity change	Mammals	Dornelas et al. 2018 Global Ecol. Bioge.

Source: this report.

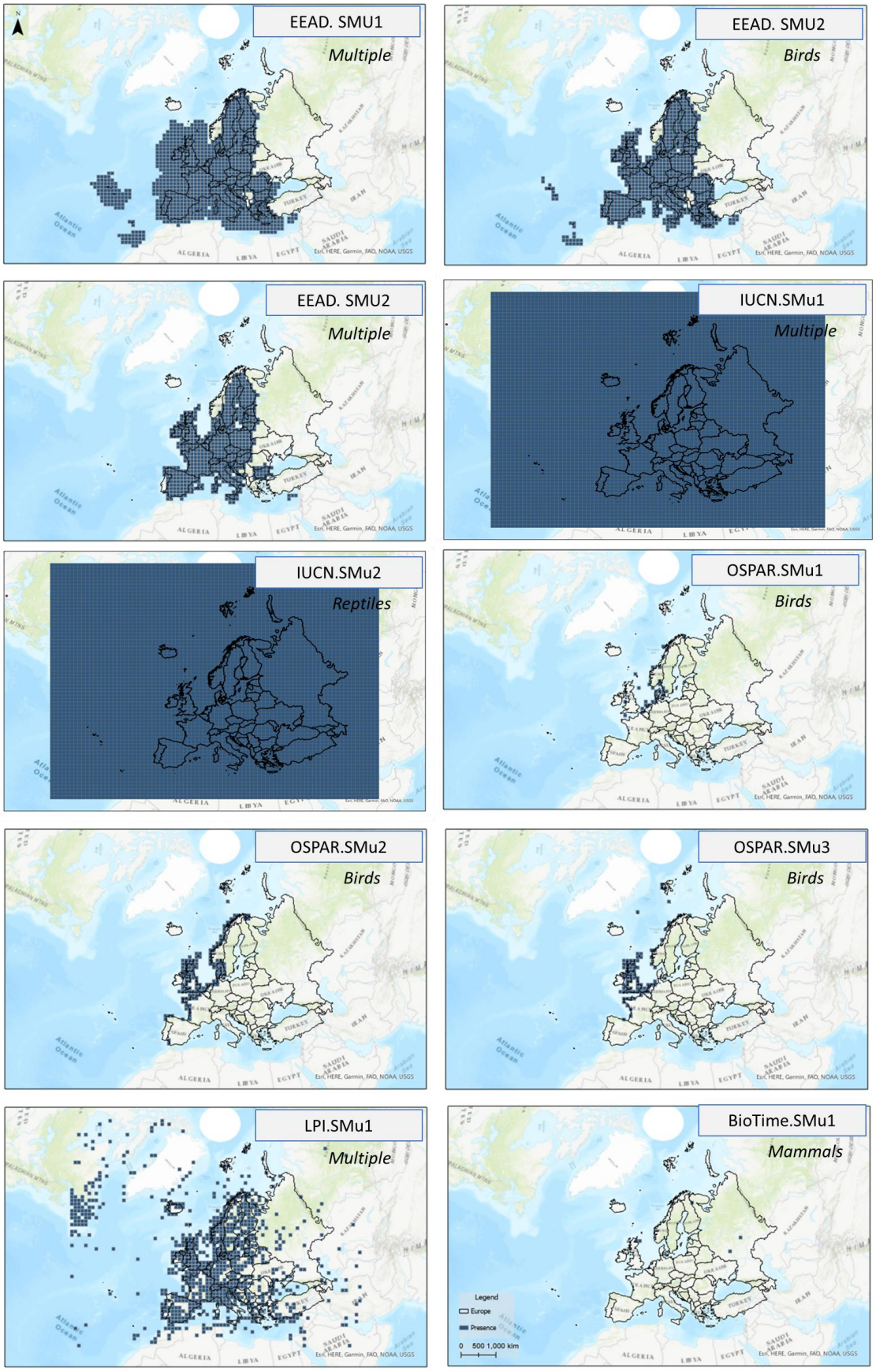
Table 22. Spatial characteristics for the datasets related to both terrestrial and marine species.

Index	Basis of record	Spatial format	File format	Coverage	Projection	Spatial resolution
BRDI.SMu1	Unspecified	Polygon	Shapefile	Global	WGS 1984	Unspecified
EEAD.SMu1	Expert observation	Polygon	Shapefile	European	ETRS 1989	Unspecified
EEAD.SMu2	Expert observation	Polygon	Shapefile	European	ETRS 1989	Unspecified

EEAD.SMu3	Expert observation	Multiple	Shapefile	European	ETRS 1989	10km
IUCN.SMu1	Modelling	Polygon	Shapefile	Global	WGS 1984	Unspecified
IUCN.SMu2	Modelling	Polygon	Shapefile	Global	WGS 1984	Unspecified
OSPAR.SMu1	Expert observation	Point	Shapefile	Sub-regional	WGS 1984	Unspecified
OSPAR.SMu2	Expert observation	Point	Shapefile	Sub-regional	WGS 1984	Unspecified
OSPAR.SMu3	Expert observation	Point	Shapefile	Sub-regional	WGS 1984	Unspecified
LPI.SMu1	Expert observation	Point	Shapefile	Global	WGS 1984	Unspecified
BioTIME.SMu1	Expert observation	Point	Shapefile	Global	WGS 1984	Unspecified

Source: this report.

Figure 19. Available datasets related to both marine and terrestrial species.



Source: this report.

3.2.7 Species Habitat

As mentioned above, the catalogue included datasets referring to species-specific habitats that were marked as "Species' habitat". Within this category, 3 datasets were considered, all related to marine ecosystems (Table 23 & 24, as well as Figure 20). The data provided by EEA and IUCN MMPATF pertained to marine mammals. The former indicated the probability of whale occurrence (EEAD.SH1), while the latter focused on important marine mammal areas worldwide (IUCN.MMPATF.SH1). Additionally, the datasets selected from UNEP-WCMC indicated the nesting sites of sea turtles (UNEP.WCMC.SH1). IUCN's and UNEP-WCMC's datasets have global coverage and are the result of expert observation procedures and modelling, respectively. On the other hand, EEA's dataset has a spatial coverage limited to Europe and was estimated through modelling techniques. It is worth noting that IUCN.MMPATF.SH1 and UNEP.WCMC.SH1 provide more accurate spatial information of the examined species, depicting specific sites where the examined species are found and function.

Table 23. Datasets included in the catalogue related to species' habitat.

Index	Data description	Species class	Reference
EEAD.SH1	Probability of occurrence of whales	Mammals	EEA
IUCN.MMPATF.SH1	Complete spatial dataset of Important Marine Mammal Areas (IMMA) around the world	Mammals	IUCN MMPATF
UNEP.WCMC.SH1	Global distribution of sea turtle nesting Sites	Reptiles	UNEP-WCMC 1999 UNEP-WCMC

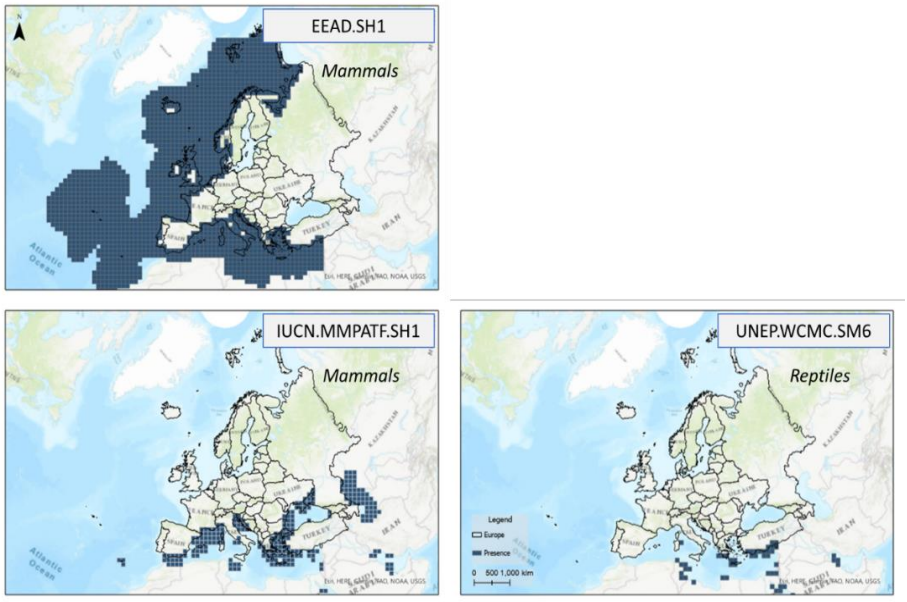
Source: this report.

Table 24. Spatial characteristics for the datasets related to species' habitat.

Index	Basis of record	Spatial format	File format	Coverage	Projection	Spatial resolution
EEAD.SH1	Modelling	Raster	GeoTIFF	European	ETRS 1989	10km
IUCN.MMPATF.SH1	Modelling	Polygon	Shapefile	Global	WGS 1984	Unspecified
UNEP.WCMC.SH1	Expert observation	Line	Shapefile	Global	WGS 1984	Unspecified

Source: this report.

Figure 20. Available datasets related to species' habitat.



Source: this report.

4 Conclusions

The landscape of biodiversity data in Europe and beyond keeps growing. We are in a position to better monitor and cover different scales with the data being generated from European and international organisations, and more detailed information emerging from several EU-funded projects and scientific initiatives. Still, we face many challenges in terms of coverage of species and ecosystems, regularity, and, especially, comparability and interoperability of data. Within the landscape of biodiversity data in Europe, most information is made available on species presence and distribution, species attributes, habitat types and species habitats, but also associated information that significantly impacts biodiversity state, such as human activities and threats to biodiversity (Costello et al., 2013). For decision and policy-making related to environmental management, it is important to be aware of which datasets and data repositories are available, their spatial and temporal attributes, as well as the information they provide and the way in which this data has been generated (Balzan et al., 2019). These datasets are also the basis for numerous research initiatives. Data collection on biodiversity has been changing over the years. The large computational capacity, along with the possibility to process big data for modelling purposes at large scales, and citizen science initiatives (Joly et al., 2016), which involve in the data collection process the non-experts, have significantly increased the amount of information and data made available and known.

On that note, within this report, we analysed the spatially explicit data available within Europe, on biodiversity information targeting mainly species and habitat level information. We reviewed a large variety of datasets from those generated by large international and European organizations, to regional and project-based initiatives and assessed their spatial and temporal attributes, the level of completeness they have, in terms of coverage and issues of accessibility and update.

Within the explored and analyzed datasets we detected a large variability in terms of coverage, completeness and biodiversity theme addressed. Overall, most data repositories host terrestrial biodiversity data with much less (6 repositories) targeting the marine environment. Some data repositories are more generic and look both marine and terrestrial systems. Out of the available repositories only 4 really target habitat specific information with only 1 targeting habitats within the marine realm. Identification of marine habitat types is not as straightforward as within the terrestrial environment, especially the further offshore one goes. Within the EU and globally several attempts are made to fill in the knowledge gaps we have on the marine environment (Robert et al., 2017; Ferrari et al., 2022) but this still requires significant field data collection and modelling effort. Among these efforts are the European Marine Observation and Data Network – EMODnet, the Oslo and Paris Conventions – OSPAR, and the Baltic Marine Environment Protection Commission – HELCOM. These three initiatives have developed web-based repositories and web GIS platforms to collect and distribute spatially explicit biodiversity data. OSPAR and HELCOM focus on the eastern Atlantic Ocean and the Baltic Sea, respectively, while EMODnet covers all European seas. It is worth noting that these datasets offer a wide range of marine ecosystem attributes such as biodiversity, human activities, pressures, etc. In most cases, the data is distributed under the same standards (accessibility, coverage, spatial format, and projection) that have been set by each management organization.

A holistic infrastructure in which environmental data integrated and distributed, have been pointed out by several studies, indicating that development and maintenance of data management system will be extra beneficial for research and conservation purposes (Conti et al., 2018, Hortal et al., 2015). From this perspective, several data repositories are available from large organizations. Within Europe, the European Environmental Agency - EEA, and the European Marine Observation

and Data Network – EMODnet, all well as global organization such as the International Union for Conservation of Nature -IUCN, the UN Environment Programme World Conservation Monitoring Centre – UNEP-WCMC, h or the Global Biodiversity Information Facility – GBIF have been structured to offer data developed either within the organizations or by third-party institutes and experts. Most of them have been serving as hubs that gather and harmonize data, allowing it to be shared and made accessible to the broader communities of policy and practice (Saran et al 2022; Bach et al 2012). Repositories such as GBIF provide structured datasets, knowledge resources and tools for analysis of the data having significantly advanced biodiversity research and management by enabling access to critical data and analytical capabilities.

EEA and EMODnet primarily offer datasets coverage for Europe, while UNEP-WCMC provides global coverage. EMODnet and UNEP-WCMC focus on marine environment data, whereas EEA covers both marine and terrestrial ecosystems. Most of the offered datasets have been generated using cutting-edge and accurate modelling techniques or acquired through expert/machine observations. These datasets are readily available for use in mapping and assessing biodiversity components. However, a disadvantage of these large data repositories is that the offered datasets is not harmonized in terms of spatial and thematic information. As a result, within these repositories, one can find datasets covering different regions, offered in different spatial characteristics, and datasets that are no longer updated or irregularly updated. This shortfall makes it difficult to utilize the datasets from researchers and end users, as it introduces bias information into the analysis procedures when multiple data need to be integrated. Therefore, efforts towards data harmonization should be integrated into the geodatabases, especially those developed and maintained by large organizations that handle various data types (Wetzel et al., 2018; Deriu et al., 2017; Babukova & Zlatunova, 2016).

When it comes to actual datasets it is worth noting that, within the marine environment our analysis indicated that we detected more information related to habitats in the marine environment. Still, this might sound like a paradox, and indeed the result is a bit misleading. In most cases, habitat information available in the marine environment, refers to the spatial distribution of a specific taxon or species. That indeed leads to an overview which shows that marine information on habitats is at a better condition than the terrestrial environment, which is indeed not the case. In terrestrial ecosystem the datasets have been developed and offered by integrating the spatial distribution of several species, especially for plants. Both marine and terrestrial habitats are developed using either modeling techniques or expert observation; however, the spatial resolution between marine and terrestrial habitat datasets differs. Marine datasets are offered at a coarser resolution with pixel size varying from 1km to 100km, while datasets referring to terrestrial habitat are offered at higher resolution (from 30m to 1km pixel size). This difference in resolution is a result derived from the initial input data, in cases where datasets have been formed using machine observation or modeling procedures. In most cases of terrestrial habitat, medium or high-resolution satellite images (such as Landsat or/and Sentinel 2 images) are used, while in the case of marine habitat, the provided datasets result from spatial interpolation procedures that often make use of raw data acquired randomly or at wide spatial intervals. However, the rapid growth of earth observation systems, which now include sensors capable of detecting marine environments features (such as Sentinel 3), can lead to the development of habitat mapping products with better spatial and thematic accuracy (Schwartz-Belkin & Portman, 2023; Yuan et al., 2023).

The aforementioned pattern is similar in the case of datasets related to species. In the marine environment, the offered datasets seems to be the majority. However, marine species datasets provide information for specific species (e.g., OSPAR provides different data for Coastal Bottlenose and Fin Whale). On the other hand, in the cases of terrestrial datasets, the majority of the datasets

has taken into account several species belonging to each taxon (e.g., Tree Atlas offers data for more than 100 tree species). This differentiation in how marine and terrestrial species data are collected, combined, and distributed is highly related to various organizations and institutes that create taxon-oriented inventories. The majority of these data repositories collect data for the terrestrial realm, such as the Botanical Information and Ecology Network – BIEN and the European Vegetation Survey – EVA, which focus on vascular plants and have created international networks of experts systematically monitoring the targeted taxon. However, there are data repositories like BioTiME that have plenty of historical and current species datasets for various taxa, although the coverage is not sufficient. Recognizing these gaps and the need for accurate biodiversity data, the EU has established a systematic monitoring program under Article 17 and Article 12 of the European Union's Directive, where its Member states are obliged to assess the conservation status of habitats and species. The offered datasets have already covered three monitoring periods (2000-2006, 2007-2012, 2013-2018), while in 2024, data belonging to the period 2019-2024 is expected. Articles 17 and 12 data are collected in a predetermined grid where several information (i.e., population size, pressures, threats, etc.) are recorded systematically. These datasets cover species from all taxa and habitat for all realms, making it the most complete dataset that can be used for policy and conservation actions at the EU level.

Overall, we detected a large variability in all aspects of biodiversity datasets that can be used to enhance species and habitat conservation status and/or develop policies towards biodiversity integrity. For such datasets to be utilized by the scientific community, policymakers, and end-users, they need to have high spatial and thematic accuracy, integrating information related to biodiversity states, pressures, and threats (Stephenson & Stengel, 2020), as well as how these characteristics have changed over the years. To overcome these limitations, a full integration of the various data stored and distributed by different institutes and organizations in infrastructure maintained by large organizations (Costello et al., 2014) like JRC and EEA would be useful. For biodiversity data to be effectively integrated into common geodatabases, homogenization procedures need to take place. However, these procedures should not only homogenize the technical characteristics of the data but also address attributes related to taxonomic incompatibility, update frequency, and permission/licensing issues (Blair et al., 2020; Feng et al., 2022). In addition, such centralized infrastructures can play a pivotal role in facilitating data sharing and accessibility, providing the scientific community, policymakers, and other stakeholders with readily available data that can facilitate insights into biodiversity components.

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List of abbreviations and definitions

AGI	Areas of global importance for conserving terrestrial biodiversity, carbon, and water
BIEN	Botanical Information and Ecology Network
BRDI	BirdLife International
DOPA	Digital Observatory for Protected Areas
EEAD	European Environment Agency Datasets
EFH	Essential Fish Habitat
EmodNET	European Marine Observation and Data Network
ETRS 1989	European Terrestrial Reference System 1989
EU	European Union
EVA	European Vegetation Survey
EWS	European woody species
GABI	Global Ant Biodiversity Informatics database
GBIF	Global Biodiversity Information Facility
GEOBON	The Group On Earth Observation Biodiversity Observation
GIFT	Global Inventory of Floras and Traits
ICES	International Council for the Exploration of the Sea
IUCN	The International Union for Conservation of Nature
LPI	Living Planet Index
MMPATF	Mammal Protected Areas Task Force
OBIS	Ocean Biodiversity Information System
OSPAR	Oslo and Paris Conventions
OPFish	Ocean productivity available to fish
UNEP-WCMC	UN Environment Programme-World Conservation Monitoring Centre
USGS	United States Geological Survey
VASC	Global patterns of vascular plant alpha diversity
WGS 1984	World Geodetic Systems 1984
WoRMS	World Register of Marine Species
WWF	Terrestrial Ecoregions of the World

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