AMBER

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D1.2 Country-specific reports containing the metadata

This is the 2.0 version of the Deliverable 1.2 Country-specific reports containing the metadata. This document is a deliverable of the AMBER project.

History of changes

Version	Date	Changes	Pages
V1.0	31.05.2017	Editorial revision of the deliverable to ensure all figures are in English	30, 31, 65, 71
V2.0	17.05.2018	Corrected version number Added history of changes	1 & 2 2

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Executive summary

This is the 2.0 version of the "D1.2 Country-specific reports containing the metadata – JRC Science for Policy Report". This document is a deliverable of the AMBER project. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 689682.

The state of river fragmentation of European rivers is largely unknown. Additionally, an exhaustive ATLAS of stream barriers at pan-European scale currently does not exist despite the critical impacts of barriers on freshwater ecosystems and ecosystem services associated with their uses. One of the AMBER project aims is the creation of the first pan-European ATLAS of river barriers that impact river connectivity. The ATLAS aims at establishing a common framework for barrier mapping, data collection and storage for any type of barrier that is likely to have an impact on river ecosystem connectivity (including water, sediments and organisms), and to support barrier reporting in a consistent and homogeneous way throughout Europe.

In the present deliverable, we describe the first results of the extensive exercise of existing database compilation and report country-specific metadata on collated databases. The report also describes how to perform the field validation of collated databases in each country and shows the results of its application carried out in Italy.

From the first analyses on databases from 13 European countries, it has emerged that few databases exist with a significant coverage at national level. Additionally, the consistency of the information collected in terms of typology of mapped barriers and list of variables stored vary significantly. Some countries have a national inventory that in most cases concerns only major dams, few have an exhaustive mapping also of minor barriers, and other countries have no information at national level. However, the comparison between these first collated databases and the results of the field validation exercise tested in Italy suggests that the amount of river fragmentation seems to be comparable amongst similar geographic areas.

- Annex A of this document reports in detail the technical steps performed to build the ATLAS structure and to homogenize the different databases collated.
- Annex B lists and describes the types of barriers included in the present report.
- Annex C reports an example of the field sheet to be used during the field validation exercise.

NB. As in other reports we are careful to distinguish between 'data collection' and 'data collation'. Data collection is where experimental work has been carried out by AMBER and this data is recorded. Data collation is where existing data sets (usually from work prior to AMBER) are gathered together to create a database.

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(*) ETL = Extraction–Transformation–Loading

1 INTRODUCTION

River longitudinal fragmentation is one of the main threats to the functioning of river ecosystems, caused by tens of thousands of man-made river barriers (Wilder et al., 2014). All major rivers in Europe are disconnected from the sea and this has had a catastrophic impact on river biota, including some iconic migratory fish species such as salmon or eels that have in some cases become extinct. River barriers also impact river physical processes in terms of alteration of the water and sediment regimes, causing changes in bed level and slope, channel width and channel pattern (e.g. Petts & Gurnell, 2013) and related habitats for biota. But river barriers also perform essential functions for society (e.g. water supply, navigation, fishing) and pose several management issues (e.g. dam removal, river restoration) (Poff & Hart 2002, Kondolf 1997).

The most up to date and peer-reviewed database of large reservoirs existing at world-wide scale is named the Global Reservoir and Dam (GRanD) database (Lehner et al., 2011; http://www.gwsp.org/products/grand-database.html). This dataset mainly focuses on reservoirs with a storage capacity of more than 0.1 km^3, even if many smaller reservoirs were added where data were available. The GRanD database includes 3,793 barriers in Europe, provided by the European Environment Agency (EEA). However, an informal and preliminary survey of available databases on the existence of river barriers in some European countries lead us to think that this number may be significanlty higher (see D1.1 Part B). Hence, the real magnitude of river fragmentation at the European scale is unknown. Indeed, there is no complete database of stream barriers in Europe, only fragmentary and incomplete data that differs in quality and coverage amongst countries. This lack of information is an obstacle to well informed decisions on barrier and river management in general. An important part of the AMBER project is therefore to create an open access, online and interactive ATLAS of stream barriers at the pan-European scale.

To this aim, we need to cope with data gaps, find an effective way to integrate and validate existing datasets and develop an open-ended user-friendly platform for future data maintenance and updates.

This report: recalls the rationale behind and aims of the AMBER ATLAS (section 2.1); reports the state of art of data collection after the strategy defined in D1.1 Part B (section 2.2); provides country-specific reports on collated databases (section 2.3); displays the first results of a comparative analysis about the presence of river barriers at pan-European scale (section 2.4); defines, tests and discusses a strategy for the validation of collated databases (section 3); provides some key recommendations for the reporting of barrier existence at country and European scales (section 4). Finally, Annex A details the ATLAS structure and how it has been developed.

2 THE AMBER ATLAS

2.1 Presentation of the ATLAS

The AMBER ATLAS aims at establishing a common framework for barrier mapping, data collection and storage for **any type of physical barrier** that is likely to have an impact on **river ecosystem connectivity** (including water, sediments and organisms), and to support barrier reporting in a consistent and homogeneous way throughout Europe. This will be achieved through an extensive exercise of **existing database compilation** and a critical analysis of the compiled data, including field validations. Physical barriers covered include all barrier heights but excludes barriers due to pollution plumes or localised low oxygen concentrations.

The ATLAS will provide a **consistent estimation** of the state of barrier monitoring across Europe. All available and accessible (to the project) data on barriers existing at national scale in every Member State will be collated and harmonized at the pan-European scale. Resources in AMBER will be cost-effectively allocated to **validate** the collated data through field activities and assess, for as many countries as possible, the quality of river barrier monitoring implemented at a national scale.

In order to guarantee consistency in terms of barrier mapping within the ATLAS, the focus will be mainly on data from **national monitoring programmes**, and regional ones will be used only when they are available and accessible consistently across the entire country of interest. To this aim, we ensured the compilation of general basic barreir attributes which can be fulfilled (in the most part) by all the database entries i.e. **11 pre-defined key variables** that are likely to be broadly available in existing databases (see section 2.2 and also D1.1 Part B). These variables allow the identification and localisation of a barrier (e.g. source ID, spatial location, river name, etc.) and provide a general description of the main features (i.e. barrier type, height and age). These have been selected after inspection of currently available databases and, in our opinion, represent the basic attributes that should be reported on the existence, type and main physical dimensions of a barrier (see D1.1 Part B for further details).

All available data European barrier data was collated. Specific sub-national scale study data, which tends to be highly more accurate than national monitoring data, was also collated in order to validate the quality of existing and official monitoring programmes at the national scale. Although there are 11 pre-defined key variables used to enable pan-European comparisons, all additional data for barrier attributes within the data sets were still retained (e.g. barrier storage, material, etc.) to enable further analysis within AMBER.

The presence of a **fish pass** was considered as a key variables. In report D1.1 (Part B) it was thought that this data would be too sparse to be useful as a key variable but after an inspection of the collated databases, it was found to be more common than expected, and was considered important for the assessment of barrier impacts.

A consistent approach is needed in order to create an ATLAS of barriers which is comparable across Europe and to enable us to estimate the quality of such mapping; assessing the degree of barrier number underestimation within each Member State, as well as for highlighting priorities and good practices for future barrier reporting in Europe.

For these purposes, existing data from different sources must be homogenized in a common format and merged into a single, centralized and relational database, i.e. the AMBER ATLAS. For further details on the **technical structure** and development steps of the AMBER ATLAS see Annex A of this report.

2.2 ATLAS data collection and metadata questionnaire

The first stage of database collation was contacting the organizations responsible for barrier management in each country. In every country, there are multiple water basin authorities and several databases on stream barriers, which have been developed and are maintained for different purposes from monitoring hydropower production to channel and river maintenance at regional and national scales. Identifying a reliable local contact point responsible for barriers mapping in each country was a challenging task and in many cases information was difficult to access.

Once the person responsible for the stream barriers in each country/region was contacted, we asked them to provide the available stream barrier databases and to also answer a questionnaire on the data provided (see D1.1, Part B, Annex A).

The questionnaire was structured as 5 main sections. The first clarifies the purposes and management policies of the ATLAS data collation, stating that the information in the AMBER ATLAS will be open and accessible. Sections 2, 3 and 5 explain how data should be provided and with an example on how to report on the metadata i.e. defining the 11 key variables relevant for the ATLAS that should be included in barrier reporting, according to deliverable D1.1 Part (Table 2.2.1). Included as a variable is "Variable name in the Source DB" (DB=database), which will enable the original source data to be identified and future linking of national databases to the pan-European Atlas (see section 2.3.2). Section 4 asks for background information about the database i.e. the original purpose of the database, the spatial scale or criteria used to report about barrier existence, and the relationship with the INSPIRE (Infrastructure for Spatial Information in Europe) database.

INSPIRE aims to create harmonised spatial data sets that can be used seamlessly in cross-border applications. D1.1 briefly discusses INSPIRE and more information is available here:
http://inspire.ec.europa.eu/
http://inspire.ec.europa.eu/documents/inspire-data-specification-hydrography-%E2%80%93-technical-guidelines-31

The data collation has focussed on the 31 EEA countries and Switzerland. Data is also being sought from countries outside the EEA, specifically in the Balkans, due to their huge interest in hydropower development and since many are candidates for future membership of the EU i.e. Albania, Bosnia and Herzegovina, Macedonia, Montenegro, and Serbia. Data will also be collated from Andorra, even though it is neither an EU nor an EEA Member, due to its location within the Iberian continent. Data for the small countries of Lichtenstein (an EEA but not EU Member) and Malta (EU and EEA Member) are not yet covered by the Atlas. Malta does not have any permanent lakes or rivers.

Table 2.2.1. Overview of the 11 key variables within the questionnaire. CO, constrained; CS, case specific. For further explanation see deliverable D1.1 Part B.

Key parameters	*Definition*	*Type*
ATLAS_ID	*New ID defined within AMBER*	*CO*
Source_ID	*ID of the source (national, regional) database*	*CS*
URL	*Link to data source. It can be, e.g.: the web address of the owner institution, the available web address of the national/regional DB*	*CS*
Country	*EU country*	*CO*
X_coord	*Latitude (WGS84)*	*CO*
Y_coord	*Longitude (WGS84)*	*CO*
River	*Name of the river*	*CS*
Basin	*Name of river basin*	*CS*
Height	*Barrier height (m), i.e. the vertical distance between the lowest point on the crest of the barrier and the lowest point in the original streambed*	*CO*
Type	*Dam, weir, spillway, etc. (*)*	*CS*
Year	*Date of building (end)*	*CO*

(*) for a more detailed list of barrier types included in the present report see Annex B.

Table 2.2.2. List of countries that will be included in the ATLAS grouped according to the level of accessibility of data to the project partners. Countries in Bold are EEA but not EU Members. Countries in Italics are neither in the EEA or EU.

	Group A	Group B	Group C
Countries	Denmark France Germany Ireland Italy Netherlands Poland Spain Sweden Switzerland UK	*Andorra* Austria Belgium Finland **Iceland** Luxemburg **Norway** Portugal	*Albania* *Bosnia and Herzegovina* Bulgaria Croatia Cyprus Czech Republic Estonia Greece Hungary Latvia Lithuania *Macedonia* *Montenegro* Romania *Serbia* Slovakia Slovenia

To gather the information of the 35 countries, the AMBER project created three different groups according to the level of accessibility of data to the project partners (Table 2.2.2):

- Group A: countries with an AMBER partner;
- Group B: countries with connections with an AMBER partner;
- Group C: countries with no connections with an AMBER partner.

Group A were the first countries where the information was gathered. Most of the questionnaires for these countries have been answered (see Figures 2.2.1 and 2.2.2). The work is now focusing on countries belonging to Group B and we are also starting the first contacts for countries in Group C. A summary description of collated data is in Section 2.3.

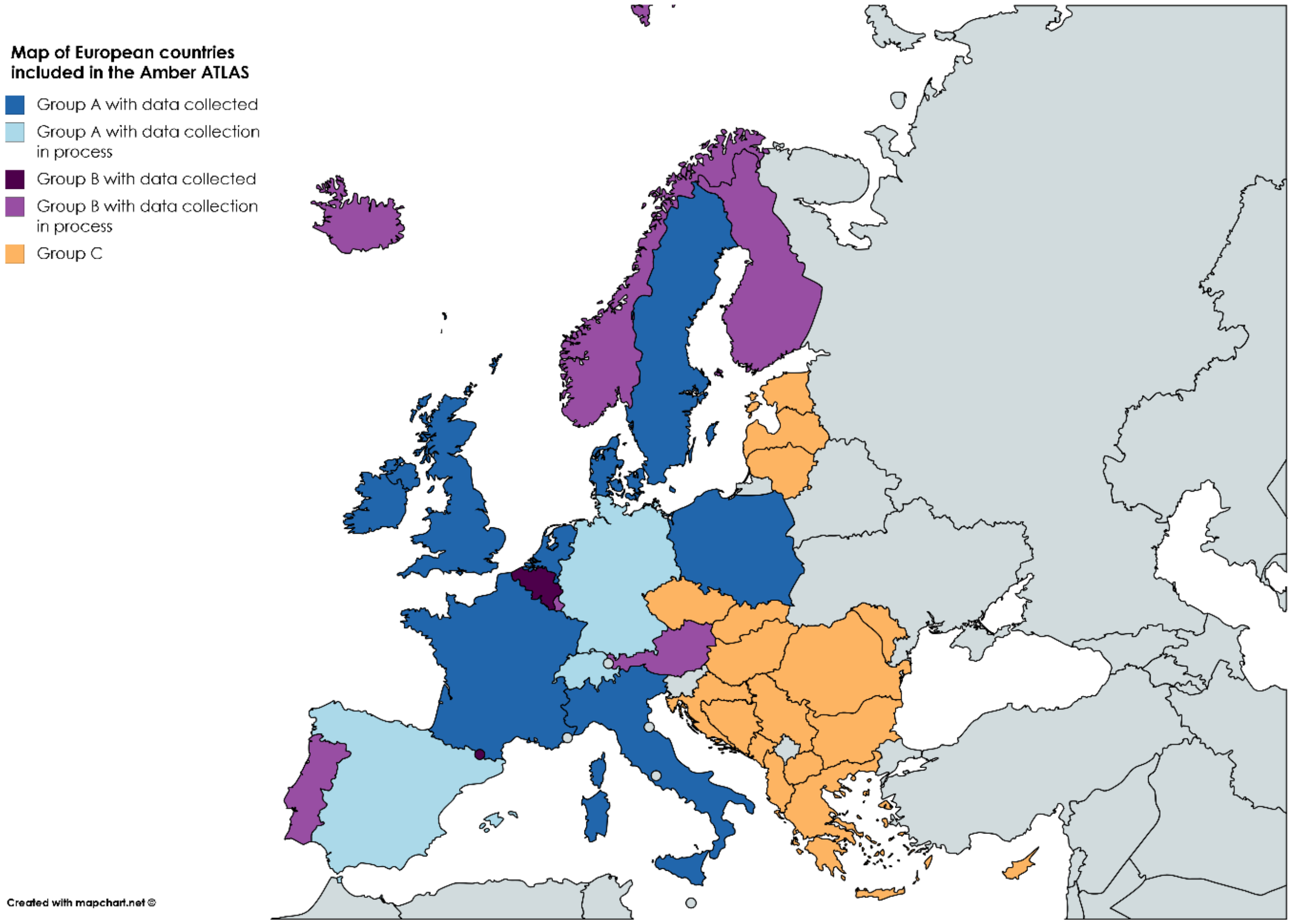


Figure 2.2.1. Status of data collection for the AMBER ATLAS (May 2017).

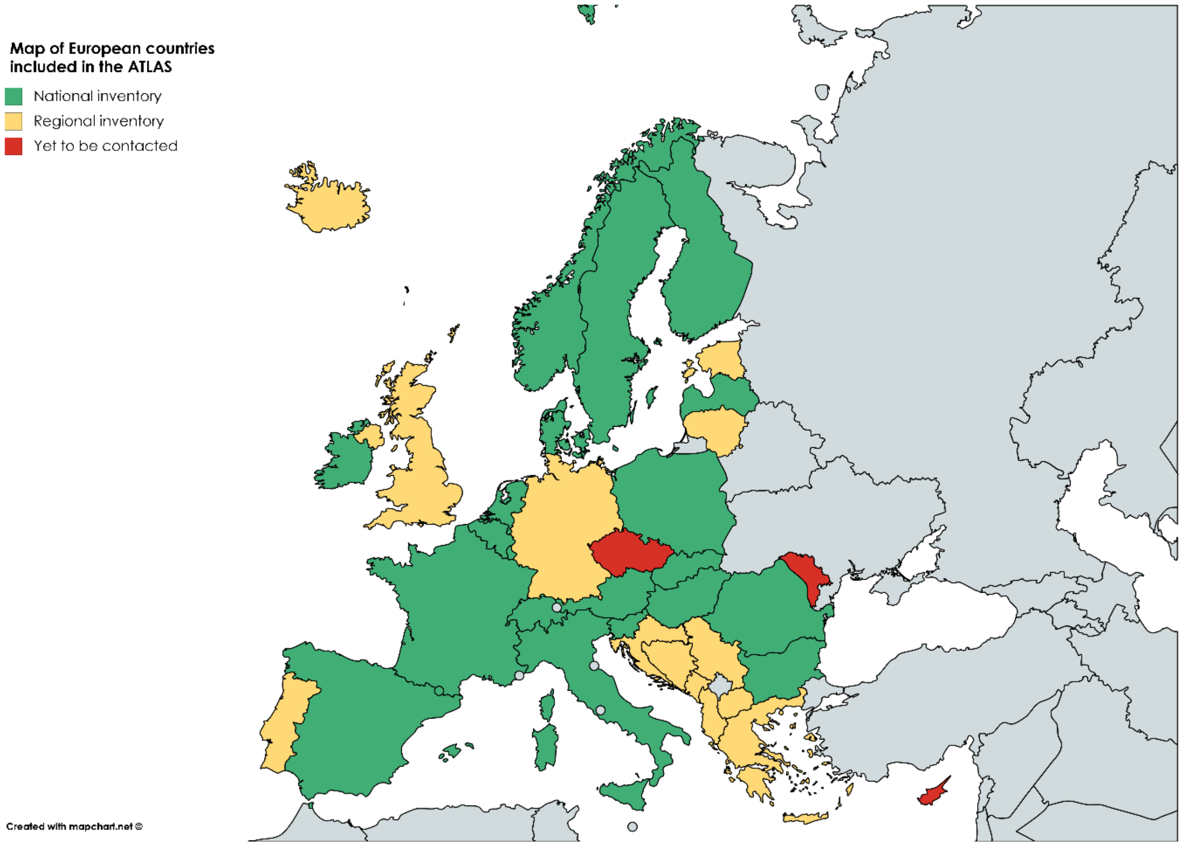


Figure 2.2.2. Map of European countries included in the ATLAS classified according to the scope of the inventory: i) National inventory existing; ii) National inventory not existing (only regional inventories); iii) No information - yet to be contacted.

2.3 Country-specific reports containing the metadata

This section summarizes the information from each collated database of the Group A countries (see Table 2.2.2), including answers to the questionnaire (see also Annex A D1.1 Part B). Table 2.3.1 summarizes whether the key variables are surveyed or not within the source database. It is worth noting that most of the key variables are included in the collated databases except the variable "year", i.e. the year in which barrier construction was completed, which is not available for any of the databases. The variable "fish pass" is available for 5 of the 14 databases included in this report.

Table 2.3.1 List of the proposed key parameters for the ATLAS and indication of whether the parameters are included (X) or not available (NA) in the source databases.

(a)

Key parameters	Denmark	France	Germany	Ireland	Italy	Netherlands	Poland
Source_ID	X	X	-	X	NA	X	X
URL (main)	NA	http://www.sandre.eaufrance.fr	-		http://www.registroitalianodighe.it	http://www.sportvisserijnederland.nl	NA
Country	X	X	-	X	X	X	X
X_coord	X	X	-	X	X	X	X
Y_coord	X	X	-	X	X	X	X
River	X	X	-	X	X	X	X
Basin	X	X	-	X	X	X	X
Height	NA	X	-	X	X	NA	X
Type	X	X	-	X	NA	X	X
Year	NA	NA	-	NA	NA	NA	NA
Fish pass	X	X	-	NA	NA	X	NA

(b)

Key parameters	Spain	Sweden	Switzerland	England	Scotland	Wales	Northern Ireland
Source_ID	X	X	X	X	X	X	NA
URL (main)	http://www.mapama.gob.es	https://biotopkartering.lansstyrelsen.se	https://s.geo.admin.ch/6f35d18806	NA	http://www.sepa.org.uk	NA	https://www.daera-ni.gov.uk
Country	X	X	X	X	X	X	X
X_coord	X	X	X	X	X	X	X
Y_coord	X	X	X	X	X	X	X
River	NA	X	X	X	X	X	NA
Basin	NA	X	NA	X	NA	X	NA
Height	X	X	X	X	X	X	NA
Type	X	X	X	X	X	X	NA
Year	NA	NA	NA	NA	NA	NA	NA
Year	NA	NA	NA	NA	NA	NA	NA
Fish pass	NA	X	NA	X	NA	NA	NA

2.3.1 Denmark

The national stream barrier database belongs to the Ministry of Environment (which is now merged with the Ministry of Food). The information is not directly accessible on-line however, it can be obtained upon request.

Figure 2.3.1. Distribution of stream barriers in Denmark. No data is available for stream barrier heights as the the heights provided were found to be inconsistent and erroneous.

The database was started in 2006 but the most recent 2011 version was provided to the AMBER project. The purpose of the database was to generate a picture of river connectivity issues in Denmark and includes 3 055 barriers. The database is not complete i.e. not all barriers are included, and it has not yet been validated. For example, important information such as barrier height is reported but it is inconsistent and no complementary information is available. Thus, it will not be possible to use the data on barrier height for the ATLAS.

2.3.2 France

The national database called "ROE- Référentiel des Obstacles à l'Ecoulement" belongs to the French Ministry of Ecology and Sustainable Development and it is directly accessible through the official web-site of the national Water Information System (WIS) data repository:http://www.sandre.eaufrance.fr/atlas/srv/fre/catalog.search;jsessionid=sup3y7zydffj6vp449fhe7ex#/metadata/5a2cdc66-36be-4bc7-be00-e04736bc7ba6; only in French).
All data, metadata and references can be downloaded at:
http://www.sandre.eaufrance.fr/atlas/srv/fre/catalog.search;jsessionid=sup3y7zydffj6vp449fhe7ex#/metadata/5a2cdc66-36be-4bc7-be00-e04736bc7ba6.
The database includes a complete inventory of French man-made barriers of all heights (i.e. 90 207 stream barriers) that have been classified by French national departments.

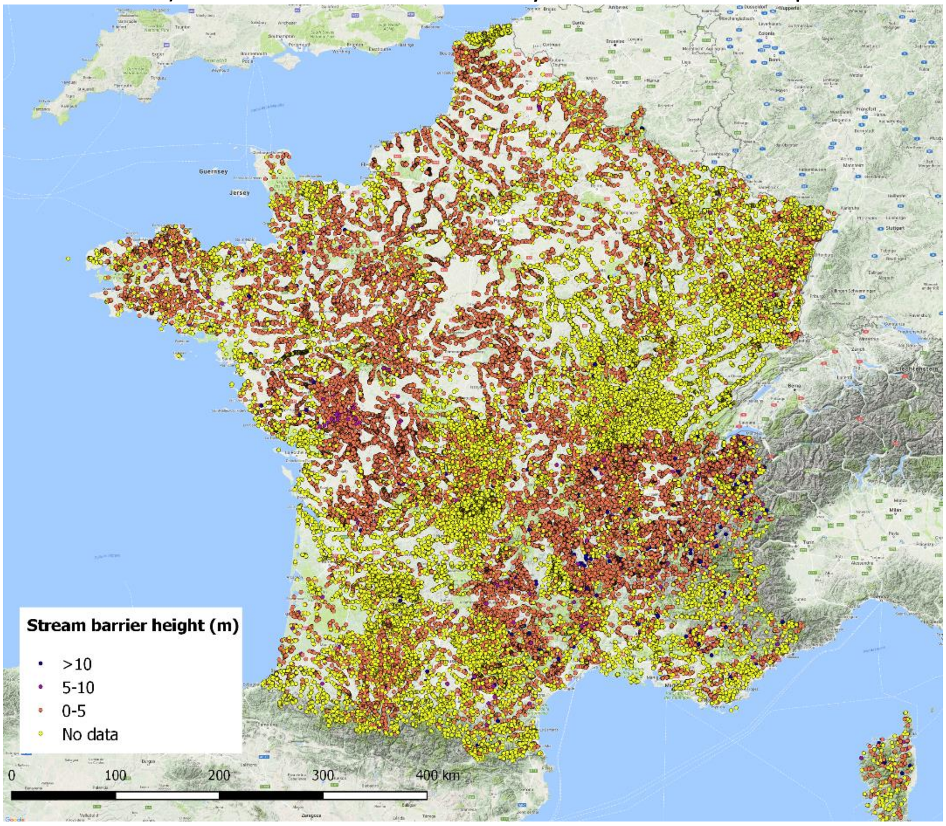


Figure 2.3.2. Distribution of stream barriers in France (metropolitan territory) according to their height.

The ROE is a data repository used for different purposes. It is a national and centralized database with the aim of listing, localizing and characterizing all man-made barriers that modify flows (with or without level difference between the upstream water level and the downstream water level). It also allows an evaluation of weir pressures, notably for river continuity or morphological alteration.
This database is compliant with INSPIRE and also with the ICE project ("Informations sur la Continuité Ecologique"). ICE is a national methodology which specifically focuses on the assessment of the impact of barriers on fish species both on upstream and downstream migration. This methodology and the data collected are coupled with ROE. However, ICE database is under construction and not yet available.
All this information has been used for the 1st or 2nd River Basin Management Plan (i.e. risk analysis, pressures/impacts analysis, decision support about management/restoration).

2.3.3 Germany

There is no national database of stream barriers in Germany and the information is spread among different local authorities. As a Federal Republic, the implementation of water resources management regulations is exclusively a matter for the 16 Federal States which form the country. In the smaller Federal States, only one authority is responsible for the data whereas in the larger ones, one authority is competent for the management level and another for the administrative level, which means both of them should have some data. In addition, Federal Waterways are managed by another authority. This has complicated data collection, and this it is still in progress.

2.3.4 Ireland

There is not an official national stream barrier database in Ireland. For the purpose of the AMBER project we have collated 1686 barriers by merging 8 databases, some available on-line from official websites, others provided upon request. The different sources are:

- 325 barriers within the Nore catchment in Ireland. This information can be downloaded at: http://wfdireland.ie/docs/20_FreshwaterMorphology/FW%20Morph%20POMS%20Assessment%20of%20the%20risks%20of%20barriers%20-%20Nore%20catchment%5B1%5D.pdf
- 72 large weirs were identified in previous projects where aerial images were used;
- 11 dams were identified by the Electricity supply board in Ireland;
- 13 barriers in Irish rivers which were impounded to form reservoirs for water supply.
- 171 barriers located after a salmon habitat assessment survey undertaken by Inland Fisheries Ireland. This information can be downloaded at: http://www.fisheriesireland.ie/salmon-management-sp-942452909/quantification-of-the-freshwater-salmon-habitat-asset-in-ireland
- 200 barriers inventoried by field staff in the Shannon Region under a preliminary analysis of known barriers within the catchment.
- The SNIFFER barrier assessment (an existing IFI database) undertaken on 39 barriers where there has been proposed modification.
- 855 barriers have been currently inventoried under TABLET, an ongoing project in which IFI field staff collect barrier information on a tablet in the field. This project is focused on specific catchments and the protocol involves visiting all potential barriers marked on aerial and ordnance survey maps (road crossing, bridges, weirs, stepping stones fords, sluices etc.). Each site is visited and assessed if deemed a barrier and subsequent measurement are taken when possible.

This database is not compliant with INSPIRE.

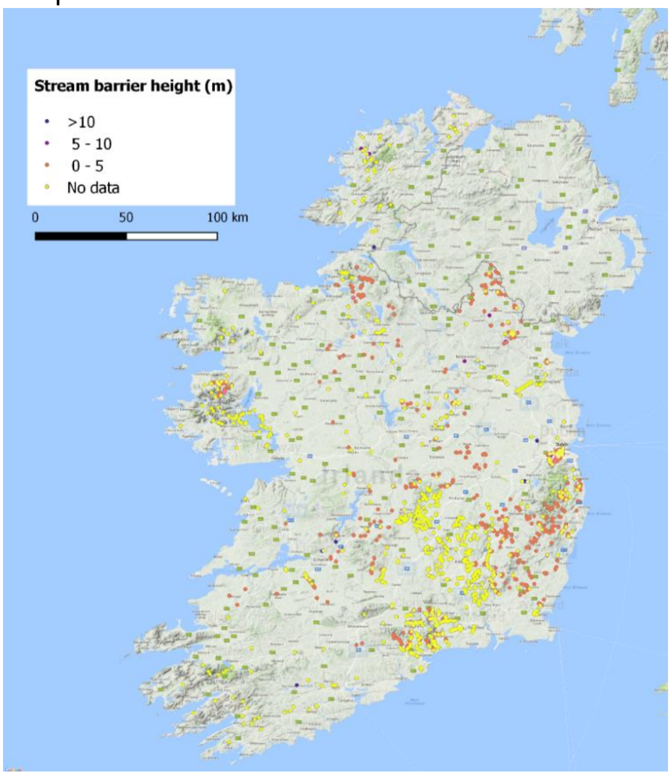


Figure 2.3.3. Distribution of stream barriers in Ireland according to their height.

2.3.5 Italy

A national database is maintained by the Italian Ministry of Infrastructure and Transport. The database is accessible through the official website:http://www.registroitalianodighe.it/, but data can only be collected upon request. They provided their database including most of the key variables (see Table 2.3.1). The official website also provides some information on the history of the institution that manages these structures, together with some links to the reference legislation.

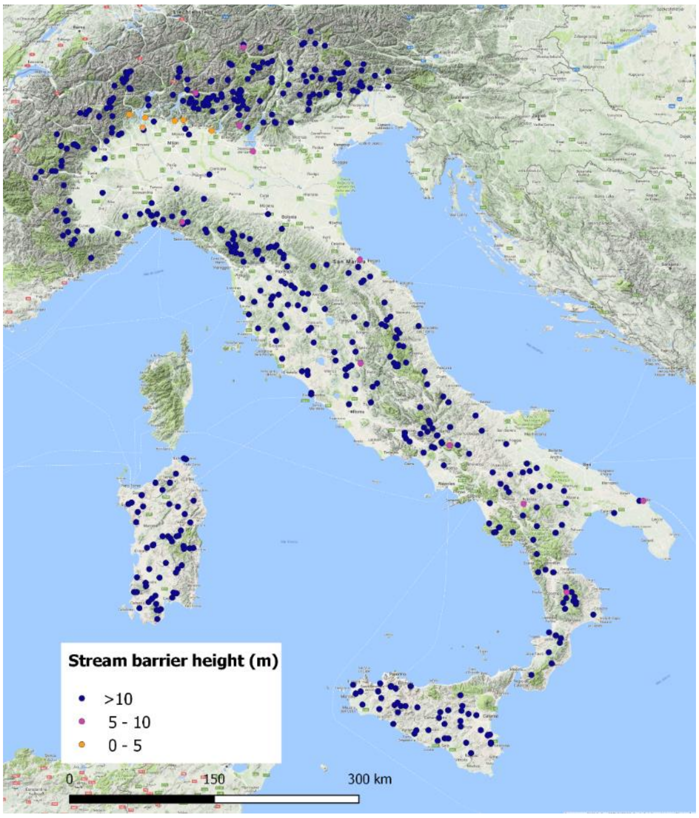


Figure 2.3.4. Distribution of stream barriers in Italy according to their height.

The database includes all the major Italian dams higher than 15m or with a storage volume greater than 1.000.000 m^3 (see Figure 2.3.4). The purpose of the database is to collect and store information on dams that are considered relevant for protection of the public safety. The database construction dates back to the 1920s. Today it is managed by the 'General Directorate for Dams and Water and Electricity Infrastructure' of the Ministry of Infrastructure and Transport, which is also responsible for the definition of the technical legislation, for the project approval of new large dams, and for the supervision of dam management.

The 534 dams reported in the database include barriers that are no longer in use as well as dams under construction. These barriers are used mainly for hydroelectricity, agriculture and drinking water supply. No additional information is available concerning the spatial scale or criteria that have been adopted to identify the river network used to report barriers existence. The database has been developed before the INSPIRE Directive came into force. For minor barriers other databases exist at the regional level or below (for instance under the responsibility of basin authorities), but this information is not consistent at the national scale and not easily accessible (see also section 3.3).

2.3.6 Netherlands

The database belongs to the Dutch Angling association, with data provided by 21 regional water authorities. The data is open and available on the official website of the Dutch Angling association. The information can be downloaded from http://www.sportvisserijnederland.nl/vis-water/vismigratie/.

Figure 2.3.5. Distribution of stream barriers in the Netherlands.

The database includes 2746 stream barriers including all types of waterbodies across the country, classified according to the Water Framework Directive (WFD). There is no information on minimum height of the obstacle surveyed, and there is no official protocol for barrier survey associated to this database. This database was built in 2015 and has not been updated since. It was built to collect information about obstacles to fish migration in the Netherlands. This database is not compliant with INSPIRE.

2.3.7 Poland

Poland has two national databases of stream barriers which belong to the National Water Management Authority (Krajowy Zarzad Gospodarki Wodnej).
The first database, created in 2008-2010, includes at least 16 000 barriers and the information is only available under request. It includes barrier location (GIS), river name, water body name, type of impoundment and fishpass presence and in some cases also information about barrier heights.
The second database, published in February 2014, includes barriers above 0.7 m height and can be visualized online: http://geoportal.kzgw.gov.pl/imap/ . River basin name, catchment name and land cover are the type of information included. There is no information about the current use of the barriers or their management.

The map displayed in Figure 2.3.6 includes an incomplete stream barrier inventory which have been provided to the AMBER project so far. There are inconsistencies in height data and the database includes only mills and small hydropower plants. The AMBER project is currently updating this information.

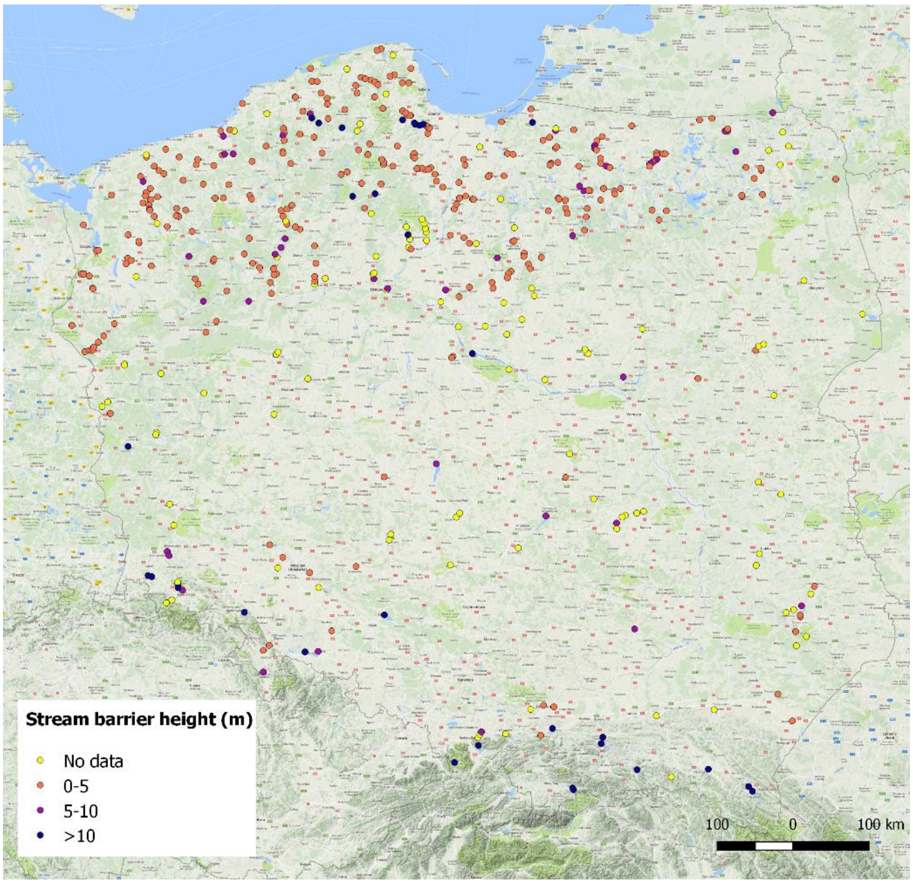


Figure 2.3.6. Distribution of stream barriers in Poland according to their height.

2.3.8 Spain

In Spain there are two national inventories called “DATAGUA” and “SNCZI” (i.e. National System Cartography of Flooding Areas). The database DATAGUA belongs to the Ministry of Agriculture and Fisheries, Food and Environment, and the information is available and downloadable on the official website (http://www.mapama.gob.es/es/cartografia-y-sig/ide/descargas/agua/datagua-2008.aspx; only in Spanish). The purpose of this database is to collect information on the type and magnitude of significant anthropogenic pressures, i.e. those that are potentially presenting a risk to the environmental objectives established by the WFD, and they are used for drafting the 1st or 2nd RBMP (River Basin Management Plan). The information available at DATAGUA-2008 corresponds to the 2008 pressures inventory carried out by the River Basin Districts applying the analysis of pressures and impacts in the first cycle (year 2008) of the implementation of the WFD.
The database includes 953 dams (including abandoned, filled and out of service) and 14350 weirs. The minimum threshold considered for weirs is a height of more than 2 meters. A new review is currently being developed by the Ministry to make improvements, suchas including the dams in the Duero Basin District which are currently absent. This database is not compliant with INSPIRE standards.

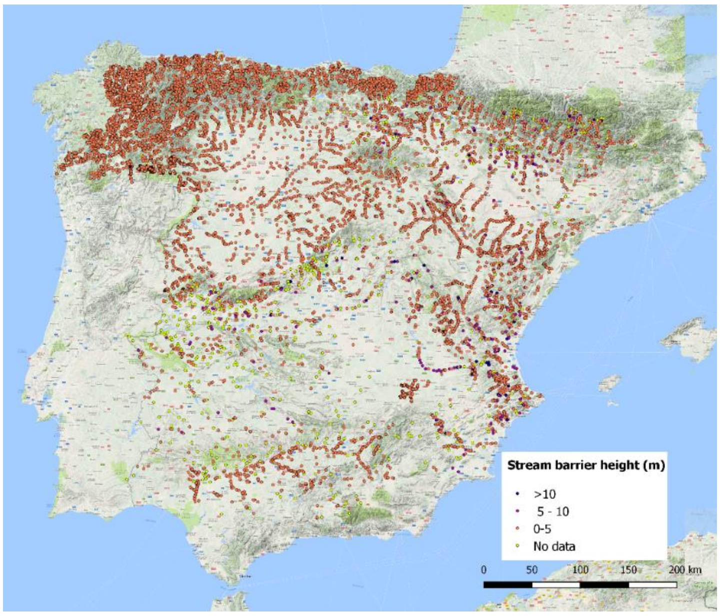


Figure 2.3.7. Distribution of stream barriers in Spain according to their height.

The second database, SNCZI-National System Cartography of Flooding Areas also belongs to the Ministry of Agriculture and Fisheries, Food and Environment and can be visualized at http://sig.mapama.es/snczi/. It is not an exhuastive inventory of barriers, but it is useful because it includes valuable information on the Spanish dams and weirs. Furthermore, it includes updated information about weirs and small dams demolished under the National Strategy for River Restoration (February 2017). This information is open and downloadable at the website http://www.mapama.gob.es/es/cartografia-y-sig/ide/descargas/agua/azudes-y-presas-obsoletas-enrr.aspx. However, the provided barrier coordinates are not correct. This error has been submitted to the competent organisation, the Ministry of Agriculture and Fisheries, Food and Environment. Thus, the database is not yet included within the ATLAS and it is not displayed in the map above (Figure 2.3.7). These databases are not complete and various regional inventories exist. However, they have not been surveyed consistently at a national scale.

2.3.9 Sweden

The database is managed by the 21 Swedish county administrative boards. This national database is available online at: https://biotopkartering.lansstyrelsen.se/frmSokVandringshinder.aspx). Relevant attributes of the database such as basin name, river name, stream barrier types are consistently reported. Information about the survey protocol and existing legislation can be found within the website. All data is in Swedish.
The database includes most of the major Swedish barriers (i.e. 24 297 including dams, fish grates, natural obstacles, lake outlets, culverts, road passage/bridges and eel hatches).

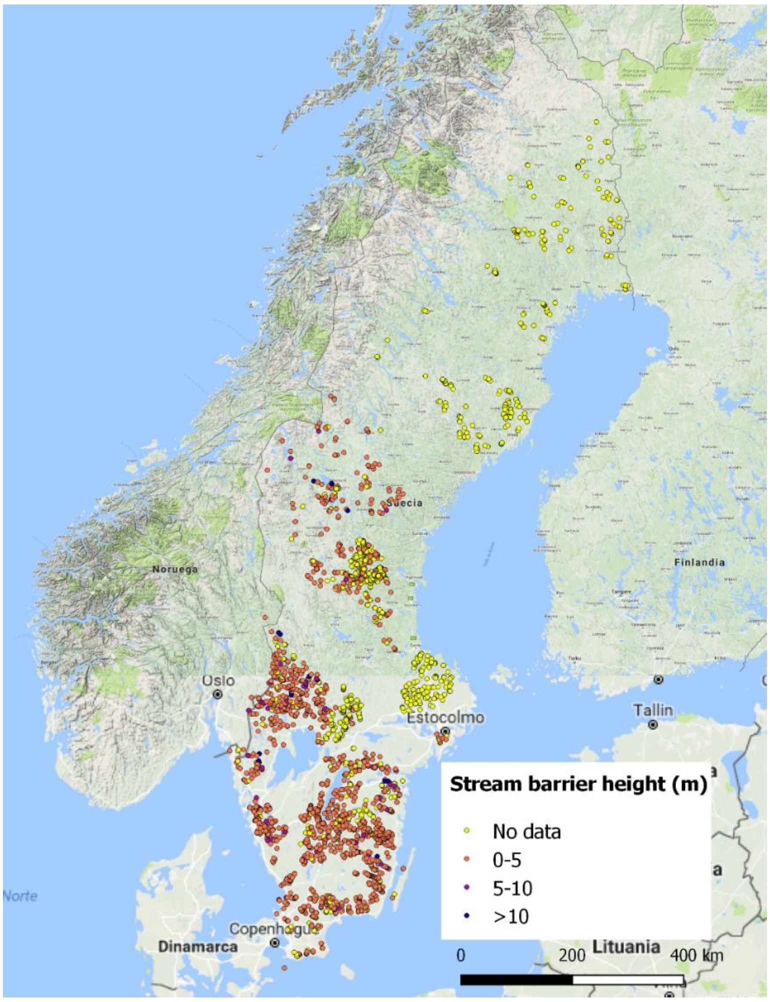


Figure 2.3.8. Distribution of stream barriers in Sweden according to their height.

The main purpose of this stream barrier inventory is as a national database for biotope inventory and migration barriers. The biotope inventory method was developed in Jönköping in the 1990's. The 21 county administrative boards of Sweden are the main providers of data. Also, the Swedish Transport Administration, Swedish Forest Agency, some municipalities and other organizations provide data. Data has been used for the WFD as a basis for the classification of hydromorphological status. This database is not compliant with INSPIRE.
There is a continuous updating policy. Authorized users such as county administrative boards, municipalities and consultants working for the institution can update the database: https://biotopkartering.lansstyrelsen.se/Default.aspx.

2.3.10 Switzerland

There are three national databases in Switzerland, available in German, French, Italian and English. The information of the three datasets is accessible in the Web-GIS https://s.geo.admin.ch/6f35d18806.

The Federal Office for the Environment has a national stream barrier inventory from the "ecomorphology" assessment which contains artificial and natural barriers, including all weirs, presumably from 20 cm height. All the information is available on-line (https://www.bafu.admin.ch/dam/bafu/de/dokumente/wasser/geodaten/oekomorphologie.zip.download.zip/oekomorphologie.zip; https://www.geocat.ch/geonetwork/srv/eng/md.viewer#/full_view/1ec44d95-573a-489c-9a57-7bc278cc6792). It contains information on hydrology, watercourse structure (ecomorphology), water chemistry and ecotoxicology, and the communities of animals, plants and microorganisms (biology). This database was built to assess the ecomorphological status/revitalization potential of freshwaters in Switzerland. The database includes two different layers on barriers: a general layer on 'drop structures' about disruption of continuity; and a specific layer on 'structure dams' that includes barriers within the river channel (e.g. weirs, floodgates, etc.). The information was provided by all the cantons (districts) in 2013 but it has not yet been validated at the country level. For instance, information on barrier type for the layer 'drop structures' is inconsistent. Thus, at this stage we only included the layer 'structure dams' within the ATLAS.

The Swiss Federal Office of Energy has a complete database of large dams under national supervision (mainly large storage dams in the alpine areas) which go from 2 to 285 m high and is available on-line (http://www.bfe.admin.ch/geoinformation/05061/05251/index.html?lang=en; https://www.geocat.ch/geonetwork/srv/ger/md.viewer#/full_view/b5225e07-9884-47b9-8bc2-161d07d1e7f2). This information includes data concerning dam functioning, geometrical and spatial parameters.

A complete inventory of all the Swiss hydropower plants with an output of at least 300 kW including technical data (e.g. production) also be found in the official website of the Swiss Federal Office of Energy (available on-line at http://www.bfe.admin.ch/geoinformation/05061/05249/index.html?lang=de&dossier_id=05264 and https://www.geocat.ch/geonetwork/srv/eng/md.viewer#/full_view/a7d239f2-4202-4760-9537-41e1a8c3c984).

The three databases are complementary but there is some redundancy amongst them (i.e. some barriers are recorded twice). They are INSPIRE compliant.

The map in Figure 2.3.9 displays data from the three databases (only one layer from the "ecomorphology" database); these are the entries which have been used in the current version of the ATLAS.

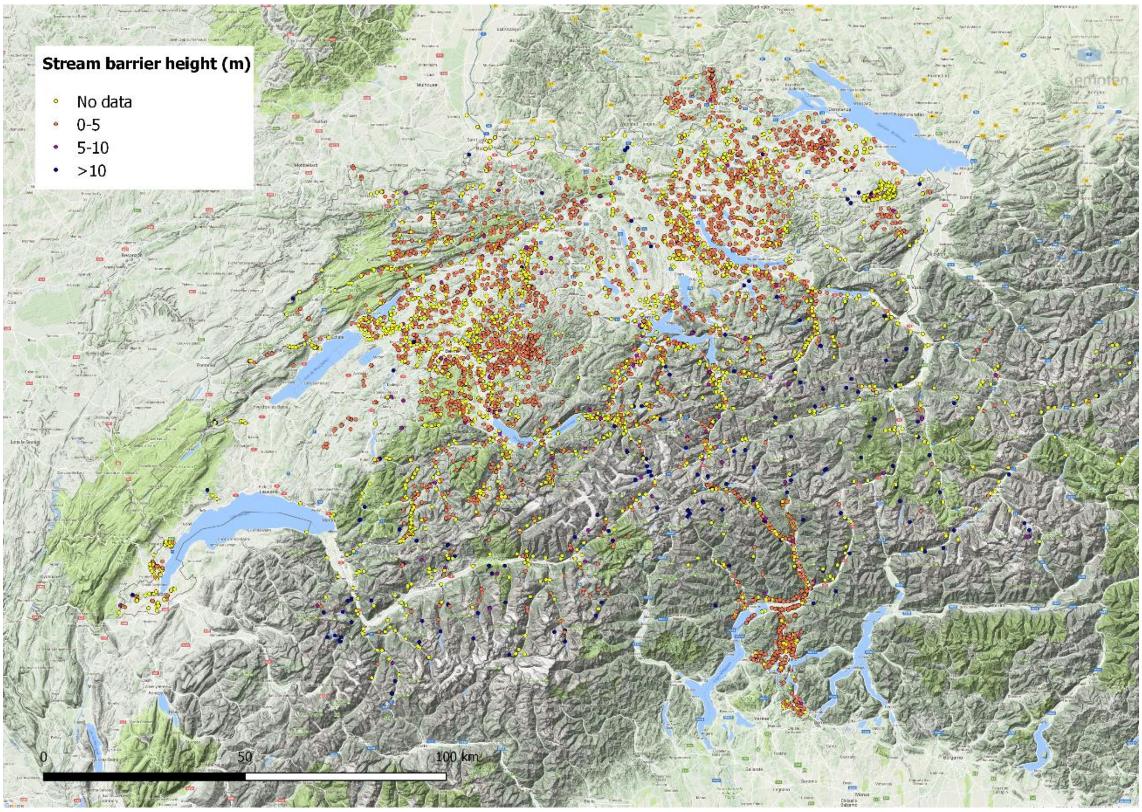


Figure 2.3.9. Distribution of stream barriers in Switzerland according to their height.

2.3.11 UK - England

England has a complete database owned by the National Environment Agency which covers both England and Wales (see 2.3.12). The report “Mapping hydropower opportunities and sensitivities in England and Wales” can be downloaded from http://www.climate-em.org.uk/images/uploads/GEHO0310BRZH-E-E_technical_report.pdf. This report describes the data survey method and the data collected.

The initial database was constructed to map hydropower opportunities in England and Wales. The original data was built in 2010 using existing inventories and processing remote sensing data. Initially 25935 barriers were identified in England and Wales using this initial methodology. Since then the database has been expanded using data from multiple sources. Currently the database in England contains 21 170 entries including all the major barriers, both natural (waterfalls up to 100 m high) and artificial (dams, weirs, barrage, culverts, fords, locks, mills and sluices).
This database is not compliant with INSPIRE.

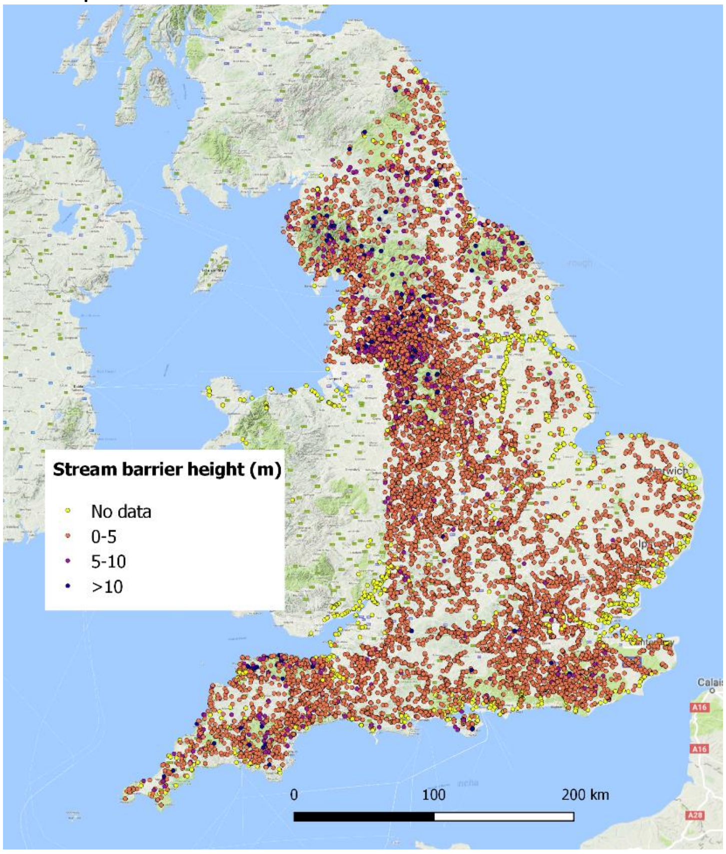


Figure 2.3.10. Distribution of stream barriers in England according to their height.

2.3.12 UK - Wales

Wales has a complete database owned by the National Environment which covers both England and Wales. The report "Mapping hydropower opportunities and sensitivities in England and Wales" can be downloaded from http://www.climate-em.org.uk/images/uploads/GEHO0310BRZH-E-E_technical_report.pdf. This report details the project for which the majority of the data was gathered, how it was gathered and why. The initial database was constructed to map hydropower opportunities and sensitivities in England and Wales. The original data was built in 2010 using existing data (e.g. high-resolution maps) and remote sensing. Initially 25 935 barriers were identified in England and Wales using this initial methodology. Since then the database has been expanded using data from multiple sources. Currently the database in Wales contains 6 104 entries including all the major barriers, both natural (waterfalls up to 100m high) and artificial (dams, weirs, barrage, culverts, fords, locks, mills and sluices). This database is not compliant with INSPIRE.

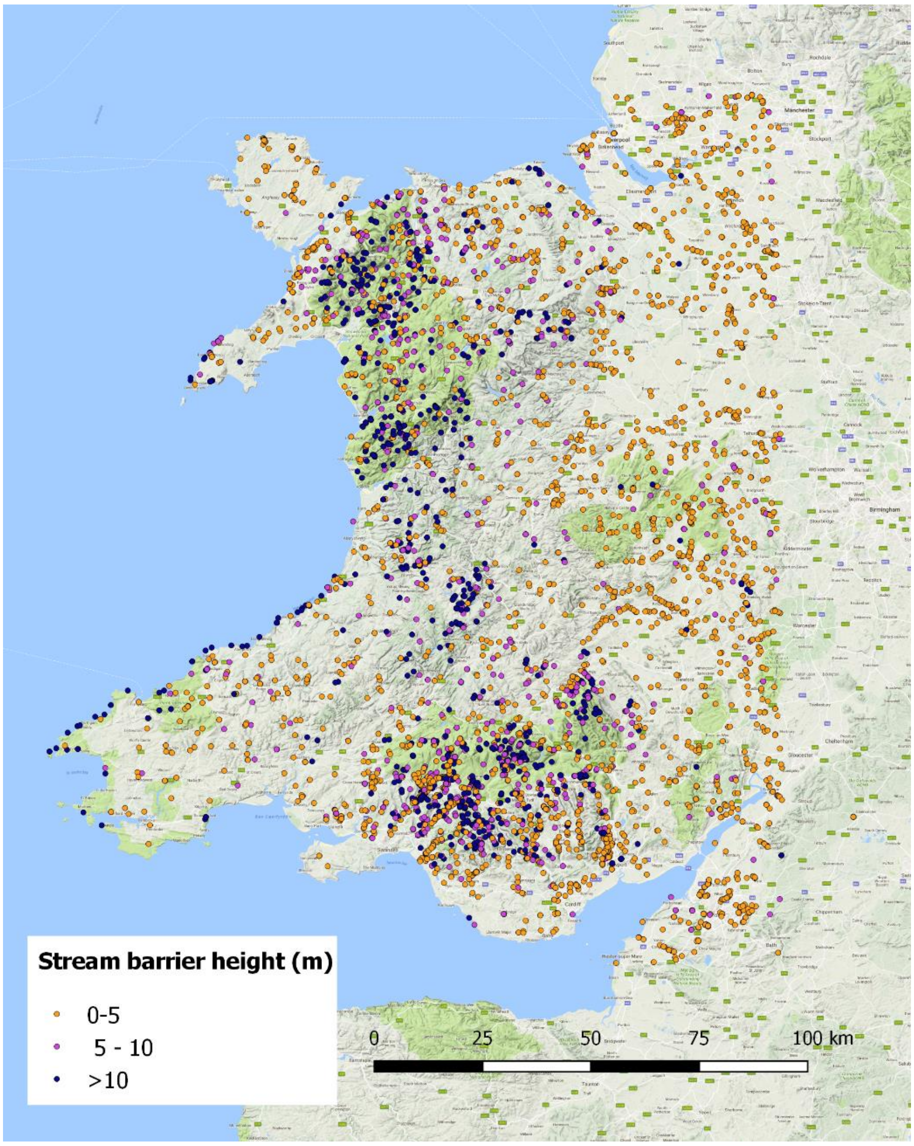


Figure 2.3.11. Distribution of stream barriers in Wales according to their height.

2.3.13 UK - Northern Ireland

In Northern Ireland, the database belongs to the Department of Agriculture, Environment and Rural Affairs - Northern Ireland (DAERA-NI). An exhaustive dataset on river barriers is not available in Northern Ireland. There are GIS files showing spatial data with 1938 recorded obstacles however, only information on longitude and latitude is available. These data were built by various projects. A report on river continuity classification in Northern Ireland and the protocol used for barrier survey is available at: https://www.daera-ni.gov.uk/publications/river-continuity-classification-2015.
The dataset was generated to assess river continuity, and barriers to fish migrations in the context of the WFD. It is not clear whether the data was used for developing River Basin Management Plans in line with WFD reporting.
This database is not compliant with INSPIRE.

Figure 2.3.12. Distribution of stream barriers in Northern Ireland according to their height.

2.3.14 UK-Scotland

The Scottish Environment Protection Agency (SEPA) is the relevant institution responsible for stream barriers in Scotland. The inventory is freely accessible and can be downloaded from the official website (http://www.sepa.org.uk/environment/environmental-data/).
There are no existing reports on barrier survey protocols.
The database includes 4 202 barriers and it has been developed to support river management practices: e.g., assess impact on river ecosystems of each obstacle and plan barrier removal measures.

Data of Scottish river barriers was used in producing River Basin Management Plans during the first, second and third cycle in accordance with policies and standards set by the WFD. A report on protocols used by SEPA to develop the River Basin Management Plans is available at http://www.sepa.org.uk/media/163445/the-river-basin-management-plan-for-the-scotland-river-basin-district-2015-2027.pdf (see pag. 27-35). An interactive map showing the condition of habitat fragmentation within each water body as identified for the WFD is available at http://www.sepa.org.uk/data-visualisation/water-environment-hub/.
Obstacle data for the current dataset has also been obtained by 'citizen science', using the app 'River Obstacles' (see https://www.river-obstacles.org.uk/reports/all-records/).
This database is not compliant with INSPIRE.

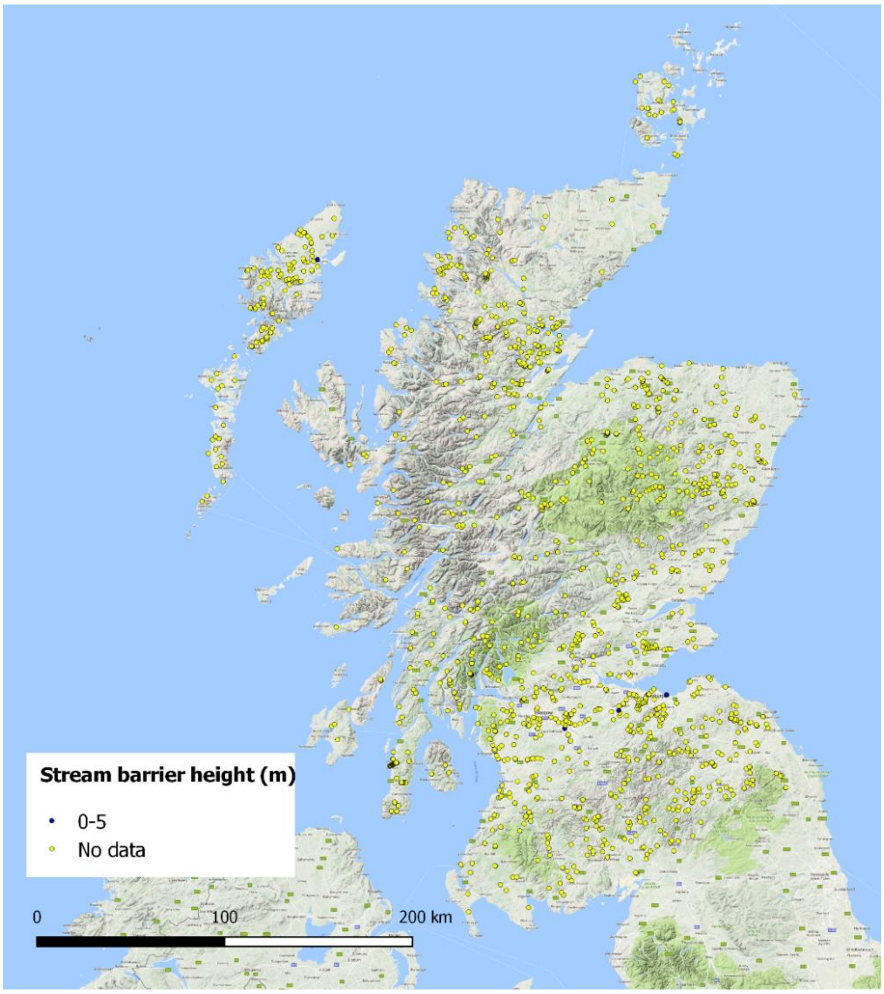


Figure 2.3.13. Distribution of stream barriers in Scotland according to their height.

2.4 Comparison between available databases

The data collection described in the previous sections has started to populate the ATLAS. In this section, we present some preliminary analysis at pan-European scale, which focuses on thirteen countries, namely: Denmark, England, France, Ireland, Italy, Netherland, Northern Ireland, Poland, Scotland, Spain, Sweden, Switzerland, and Wales.
Figure 2.4.1 plots the locations of the 147 908 barriers recorded in these thirteen countries. The point's color relates to the barrier density per river kilometer calculated at national scale, i.e. the number of barriers reported in each country is divided for the total length of the national river network. We used the European Catchment and Rivers network system (ECRINS; http://www.eea.europa.eu/data-and-maps/data/europeancatchmentsand-rivers-network#tab-gis-data), that is a composite geographical information system (including river network, river catchments and lakes) where the river networks have been defined at Pan-European scale on common criteria using a 100 m resolution Digital Elevation Model.

France, England, Wales, Switzerland, Northern Ireland and Denmark have comparable density with between 0.3 and 0.5 barriers every river kilometer. The Netherlands has the highest density with 0.83 barriers per river kilometer. Other countries have much lower density, as it is also visible observing the density of points in each country: Italy and Poland for instance, have respectively 0.0038 and 0.0058. This difference is associated to the different purposes the databases have been built for. In France, England, Wales, Netherland, Northern Ireland, Switzerland and Denmark the national database includes all kind of river barriers from small weirs (less than 1 m) to major dams, whereas in Italy, for instance, the only database existing at the national scale includes only major dams namely, higher than 15m or with a stored volume higher than 1Milion of m3 (for details see Section 2.3). Indeed, if we plot only barriers higher than 10 meter, we obtain Figure 2.4.2 where barrier density is fairly low in between 0.0003 and 0.0006 for Sweden, Ireland, Spain and Poland, higher and comparable between Italy (0.0037) and France (0.0023), and the highest values are reported in England (0.0153), Wales (0.0310) and Switzerland (0.0117).

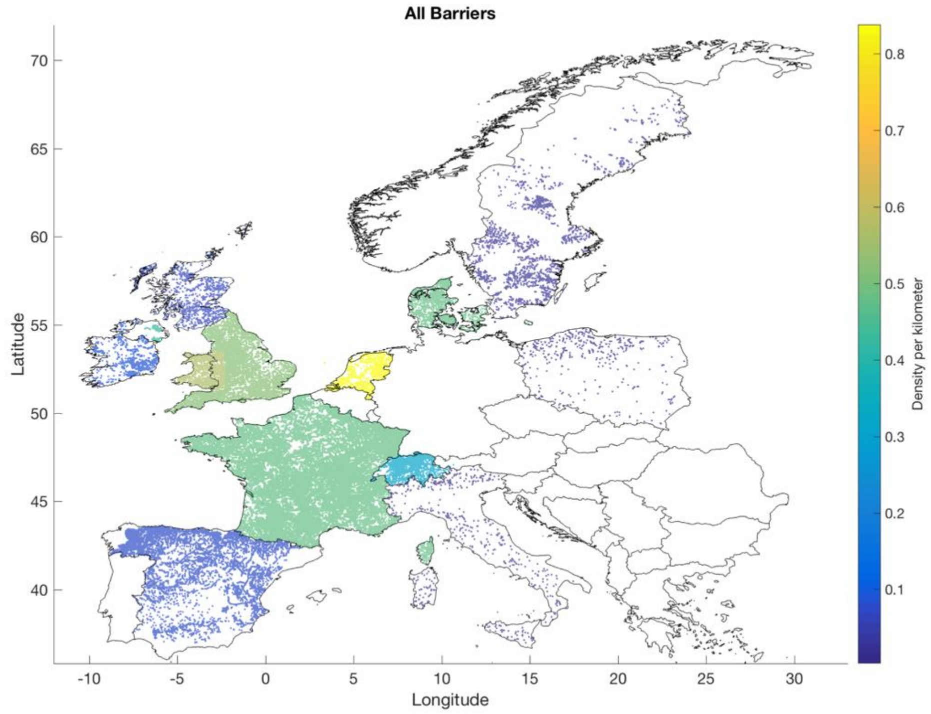


Figure 2.4.1. Density of barriers per river km (for each country) including all barriers present in the databases

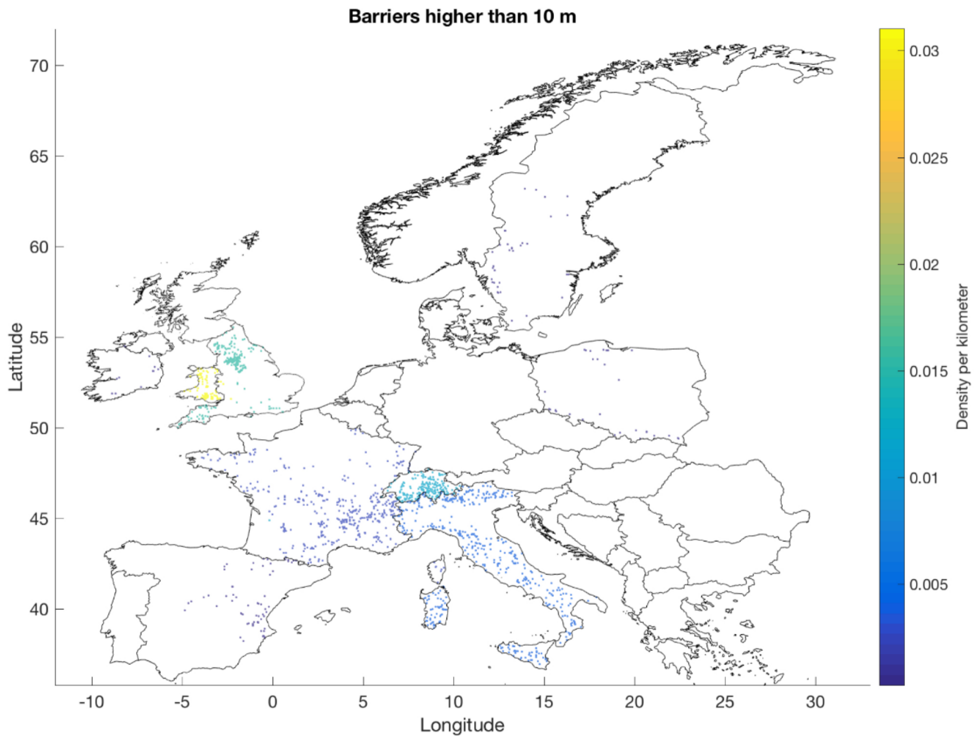


Figure 2.4.2. Density of barrier per river km (for each country) including barriers higher than 10 m.

When we examine barrier height pie charts for the database (Figure 2.4.3), we can observe the following points:

- Height, which is a key physical parameter and relatively easy to be monitored, is missing in a significant amount of data samples: in the France database, which is very detailed (90 170 barriers) 53% of the data entries have no information on barrier height; in Sweden 37% of the data is without barrier heights, in Ireland 58%. Denmark, Northern Ireland and the Netherlands have no or inconsistent information about height.
- High density databases (such as in France, England, Wales, Switzerland and Sweden) which have height data, show that the majority of barriers are lower than 10 m: in France 38% of barriers recorded are between 0-2m; in England, 45%; Sweden 42%; Ireland 36%; Wales 33%; and Switzerland 45% (although still unvalidated). Barriers above 10 m are less than 2% of the data records for these countries except in England (3%) and Wales (5%).
- Poland, Spain and Italy show a different pattern of height distribution, which is due to the more selective coverage of the data bases. For instance, Poland's database includes only small and medium hydropower plants (see previous sections for more detail information about the status of data collection for each country and the nature of the respective data sources).

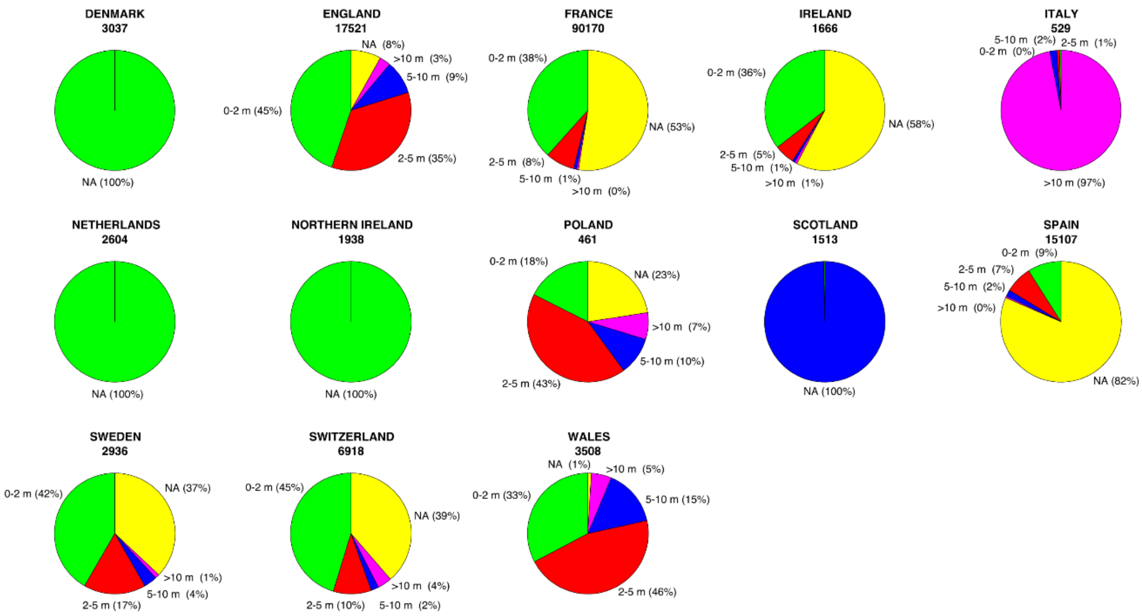


Figure 2.4.3. Subdivision of barriers per height classes for each country. Number below the country's name is the total number of barriers present in the national database

Another key parameter of the ATLAS is barrier type (see Table 2.2.1). Figure 2.4.4 plots pie charts for barrier type as classified in each national database. Here, for readability purposes, only the most common types representing more than 2% of the entries in their respective database are visualized. Types are reported in most of the countries except Poland and Italy since both these databases are already specific barrier types: small and medium hydropower plant, and major dams, respectively. Similarly, Spain's database mainly records weirs and different types of dams (e.g. gravity dams) that are relevant at the national level. Despite most of the countries reporting information on barrier type, there is a wide range of terminologies which are not consistent between countries, except for types such as dam, weir, or culvert (see Wales, England, Ireland, France, Scotland, Sweden). In the thirteen countries analyzed there were 293 different types of barriers are defined. Different countries have varying levels of precision in defining a barrier type. For France and Denmark have many different barrier types, whereas Sweden only has a few. However, most of the diversity in barrier types within the databases are for a very limited number of entries. Thus, of the 293 barrier types, most are not reported in Figure 2.4.4 since they cover less than 2% of the entries in their respective national database.

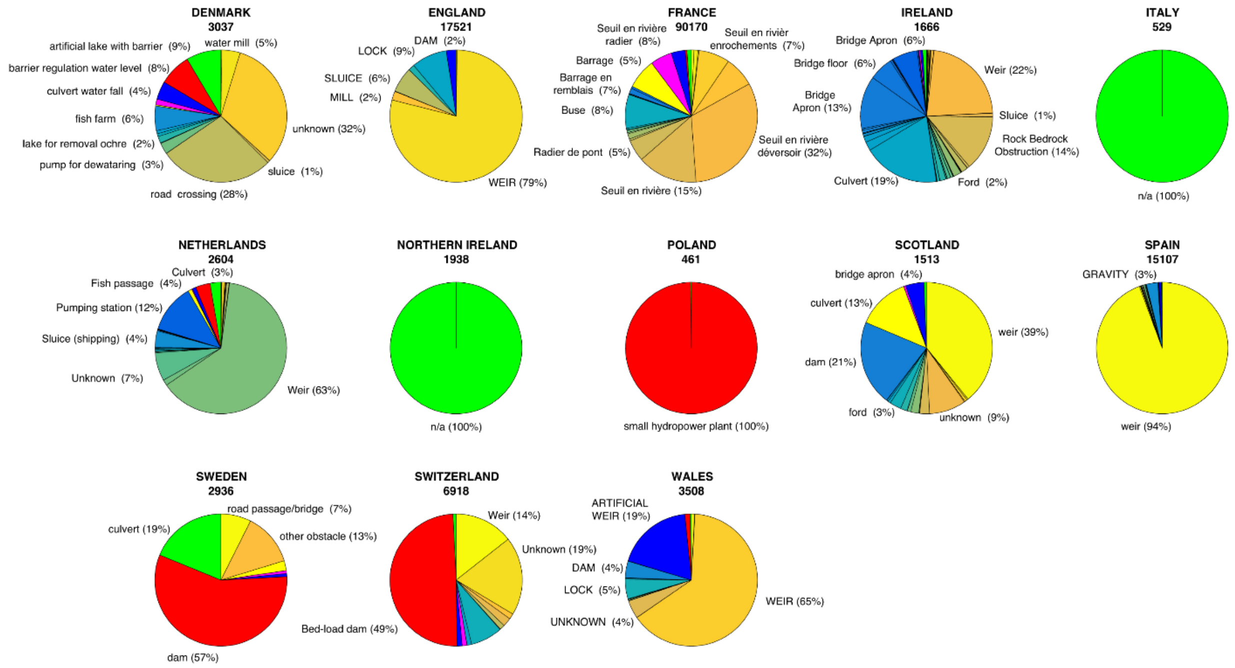


Figure 2.4.4. Subdivision of barriers per type as defined in each respective country. Number below the country's name report the total number of barriers present in the national database. French barrier types: Seuil en rivière= weir; Seuil en rivière deversoir = spillway weir; Seuil en rivière radier = slope weir; Seuil en rivièr enrochement = ramp weir; Barrage = dam; Barrage en remblais = embankment; Buse =culvert; Radier de pont = bridge apron.

As a final step, we examined where there was data on fish passage occurance (see Figure 2.4.5). Although not initially conisdered important (Table 2.2.1) it is now considered to be useful as a key parameter (Table 2.3.1). Although this parameter is missing for most of the databases, it is present in Denmark, England, Sweden, Netherland and France. In Denmark around half of barriers have a fish passage, whereas in France and Sweden less than 10% do.

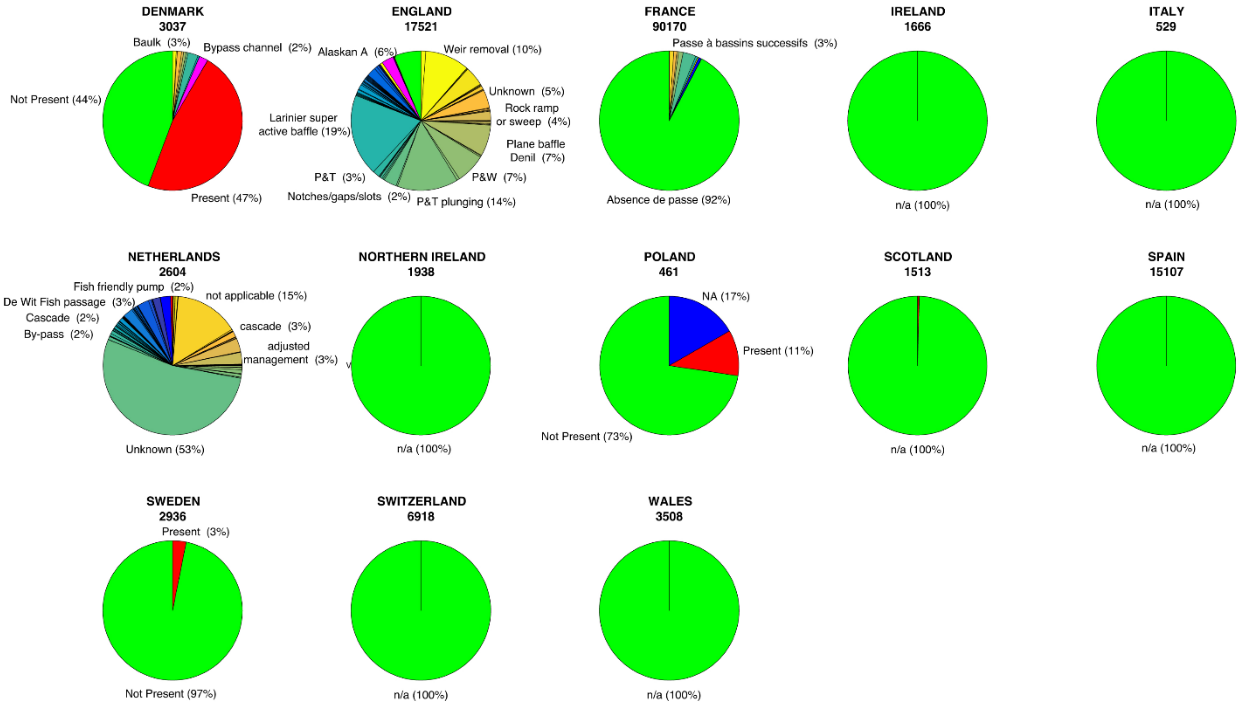


Figure 2.4.5. Subdivision of barriers per fish passage classes as defined in each country. Number below the country's name report the total number of barriers present in the national database. French fish pass types: Passe à bassins successifs = pool-weir fishway; Absence de passe = no fish pass.

3 VALIDATION EXERCISE

The aim of this exercise is to validate, through field surveys, existing barrier databases and assess for as many countries as possible the quality of river barrier monitoring implemented at a national scale. Accurate and focused study data covering small areas (compared to the country), will also be used to validate the quality of existing official national scale monitoring programs. This approach is needed in order to generate a consistent ATLAS of barriers across Europe and to estimate the quality of such mapping, the degree of barrier underestimation in each country, and highlight priorities and good practices for future barrier reporting in Europe.

3.1 Validation strategy

The basic spatial data that will be used for the entire validation exercise is the ECRINS geodatabase (i.e. European Catchment and Rivers network System; https://www.eea.europa.eu/data-and-maps/data/european-catchments-and-rivers-network , which includes river networks, river catchments and lakes. In particular, the river network of the ECRINS database will be used to determine the density of barriers per river kilometer in each country.

For field validation purposes, we plan to cover 100 km of river length per country, by surveying 5 different rivers broadly representative of the river types in that country. The whole validation exercise will include the following steps:

I. Field data collection by recording variables consistent with Tier-1 of the AMBER smartphone app (i.e. barrier location, picture, type and height, barrier use and width; see section 3.3). This will consist of recording all the barriers encountered along a river section for a total of 100 km of river length per country (see section 3.3).
II. Validation: numerical estimation of the accuracy of barrier coverage comparing existing DB and results of field data collection. It is intended to provide accurate estimation of barrier density per river length for the existing databases compared to the field survey. Data on barrier type (i.e. description of some basic characteristics, e.g. type and height) can also be checked for completeness.

The following sections explains how to carry out Step I and provides a practical example for Steps I and II.

3.2 Guidelines for the selection of field sites and field validation work

3.2.1 Site selection

The selection of 5 different rivers is based on expert opinion following some basic criteria (Table 3.2.1). For each river, 20 km of river length must be surveyed. The 20 km should correspond to the distance measured along the river channel. The rivers 20 km river reaches have to:

- Be broadly representative of different conditions in terms of physiographic setting, i.e. altitude and slope, and river types existing in a country in accordance with Table 3.2.1 (see also Figure 3.2.1);

- Include both rivers that flow into the sea and tributaries of main rivers (e.g. proportions could be 3-2 or 2-3), also trying to include small order river stretches (but refer to the spatial coverage of the ECRINS network);
- Be located, as far as possible, in different biogeographical and socio-economic areas;
- Be easily accessible.

Table 3.2.1. Main criteria to select rivers and river sections for field validation

Name	Classes	Rough reference values
Altitude	Lowland	<200 m a.s.l.
	Mid altitude	200 - 600 m a.s.l.
	Mountain	> 600 m a.s.l.
Slope	Low slope	< 0.02 $m.m^{-1}$
	High slope	> 0.02 $m.m^{-1}$
River type	Single-thread	Number of channels = 1
	Multi-thread	Number of channels > 1

The criteria in Table 3.2.1 are considered relevant in identifying broad categories of river types roughly consistent with the WFD categories (System A) and with recently published river morphological classification for management purposes (Figure 3.2.1; Rinaldi et al., 2016).

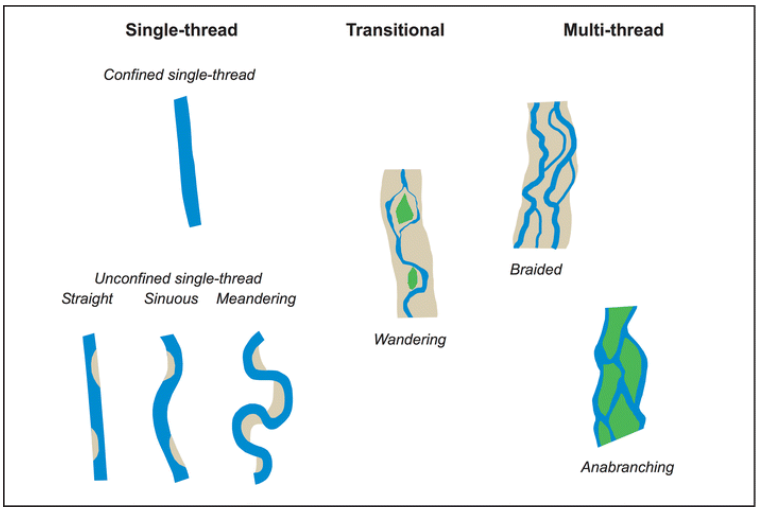


Figure 3.2.1. Basic river types. Extracted from Rinaldi et al. (2016).

We are aware that the sites selected in that way aren't exhaustive of the range of river types existing in a country. We are also aware that all the validation, including estimation of barrier number, has bias dependent on the strategy chosen and the resources available. However, this strategy allows us to represent a wide range of river types and conditions in a country and represents the best compromise (given the available resources) in providing a good picture of river barrier density at the national and pan-European scale.

3.2.2 Field work

At least two experienced people will carry out the field validation in each river during August-October 2017 (or spring-summer 2018 if not possible in 2017). The field will be done under low summer water levels (Q_{95}+ annual exceedance, ideally).

The operators will survey two 10 km contiguous sections of a river, for each of the five rivers, walking along the river banks (as much as is practical). All barriers to river connectivity must be recorded, as well as the variables consistent with those collected within Tier-1 of the smartphone app (Table 3.2.2) i.e. a picture, location, date, barrier type, barrier height (class), barrier use (still in use or not) and barrier span width (spanning full width of river or not). The description of barrier types can be seen in Annex B. An example of the field sheet that includes variables of Table 3.2.2 is reported in Annex C.

Table 3.2.2. Variables to be surveyed in the field consistently with the APP (for each encountered barrier)

Name	Description
Picture	A photo of the barrier – provide a reference for the picture
Location	Lat/Long coordinates for e.g. via GPS chipset on phone
Date	Date of record in format day/month/year
Barrier type	Dam, weir, culvert, ford, ramp and bed sill, sluice, unknown
Barrier height	<0.5 m, 0.5 - 1.0 m, 1.0 – 2.0 m, 2.0 – 5.0 m, 5.0 – 10.0 m, >10.0 m
Barrier use	Barrier still useful/in-use, Y/N/don't know
Barrier width	Full width, Y/N

For each 10 km of river section the parameters in Table 3.2.3 should also be calculated, in order to justify and validate the field site selection. These parameters will also be used later in the project, during a further step of the validation exercise (e.g. to see how barriers are related to geographic drivers).

Table 3.2.3. Basic and additional criteria to be calculated in order to justify and validate field site selection

Name	Description
Altitude	Mean altitude of the 10 km river section in m
Slope	Mean slope of the 10 km river section in $m.m^{-1}$
River type	Single-thread or Multi-thread
Sinuosity	Distance along the (main) channel (10 km) / Distance following the direction of the overall planimetric course
Landuse	Level 1 of Corine Land Cover classification

3.3 Example of field validation: the Italian case

The validation strategy described in sections 3.1 and 3.2 has been tested in Italy. The field work was performed during the 2nd week of April 2017. It required 4 people and 5 hours per river for a total of 5 days of work.

3.3.1 Selected Italian sites for field validation

According to the guidelines described in section 3.2, we selected five rivers and related 20 km of river reaches that cover a range of river types and conditions (Table 3.3.1). Three of the selected rivers are tributaries of the Po River basin, the main Italian large river (basin area of 71 000 km^2, see Figure 3.1). The other two rivers (the Marecchia and the Arno) flow directly into the sea (Figure 3.3.1), with river basins areas of 611 km^2 and 8 508 km^2, respectively. These rivers drain the Apennines and are located in the Emilia-Romagna and Toscana regions (respectively), representing different geographical and economic areas of Italy.

The three tributaries of the Po river studied are mainly located in the Piemonte Region, two along the Alps and one along the Apennines (Orco, Dora Baltea and Scrivia, respectively). These have been selected for practical reasons in order to maximize the work effort (proximity to Milan) and because in the Piemonte region there is a regional and public database of river barriers which the validation data can be compared to.

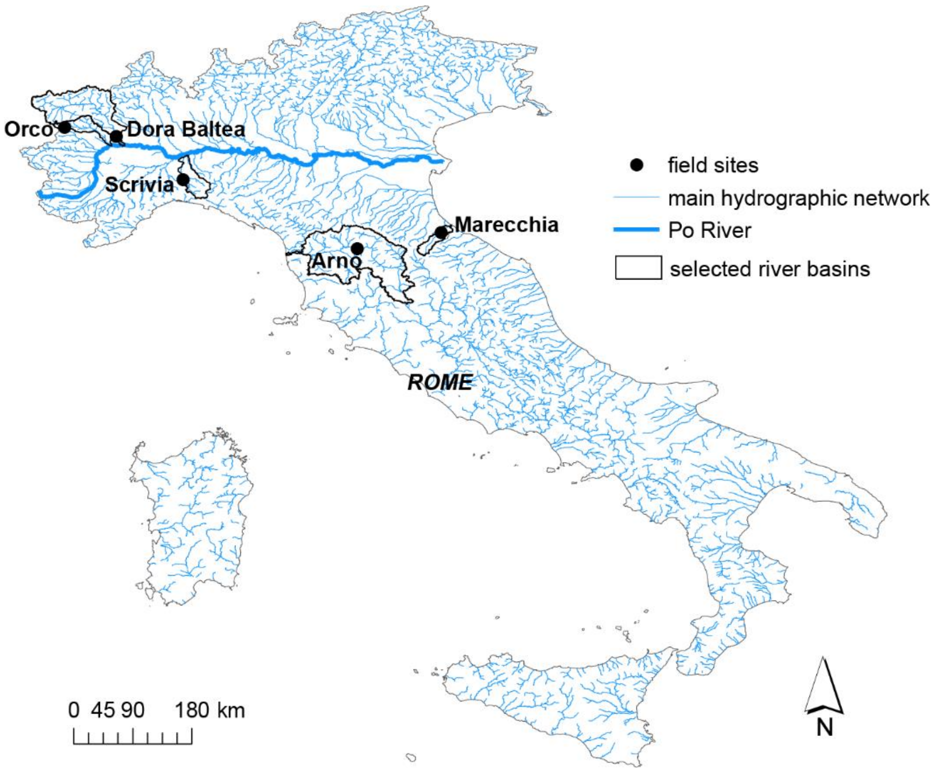


Figure 3.3.1. Location of the five selected rivers and sites for field validation.

Table 3.3.1. Summary information about selected rivers in order to justify and validate field site selection. River sections: 1, upstream; 2, downstream. River type: ST, single-thread; MT, multi-thread. Landuse (Corine Land Cover 2006): 1, Artificial surfaces; 2, Agricultural areas; 3, Forest and seminatural areas. For better details about variables, see section 3.3.2.

Name	Section	Orco	Scrivia	Dora Baltea	Marecchia	Arno
Altitude (m)	1	1915	209	244	157	61
	2	1217	196	194	77	43
Slope ($m.m^{-1}$)	1	0.06	0.006	0.0009	0.008	0.002
	2	0.07	0.004	0.002	0.008	0.001
River type	1	ST	ST	ST	MT	ST
	2	ST	MT	ST	ST	ST
Sinuosity	1	1.14	1.06	1.31	1.06	1.09
	2	1.11	1.18	1.67	1.05	1.08
Landuse	1	3	2	2	2	1
	2	3	2	2	2	1

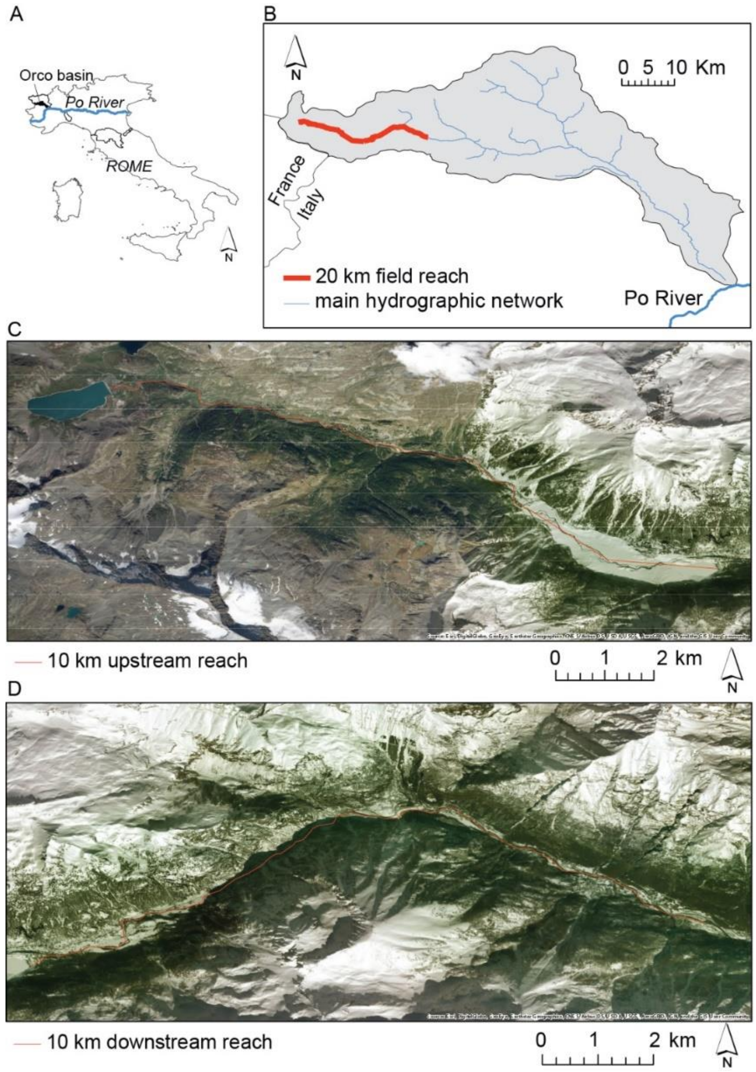


Figure 3.3.2. The Orco river. A, location of the river basin within Italy. B, location of the 20 km river reach selected for field validation. C and D, overview of the upstream and downstream river sections, respectively.

The Orco river reach is located in the upper part of the river basin in the mountain area above 1000 m a.s.l. (meters above sea level) (Table 3.3.1, Figure 3.3.2). It presents high slopes (> 5%), and a single-thread channel pattern, often dominated by a bedrock channel. It is an Alpine tributary of the Po River. The selected 20 km of river reach are located in the forested area of the Gran Paradiso National Park.

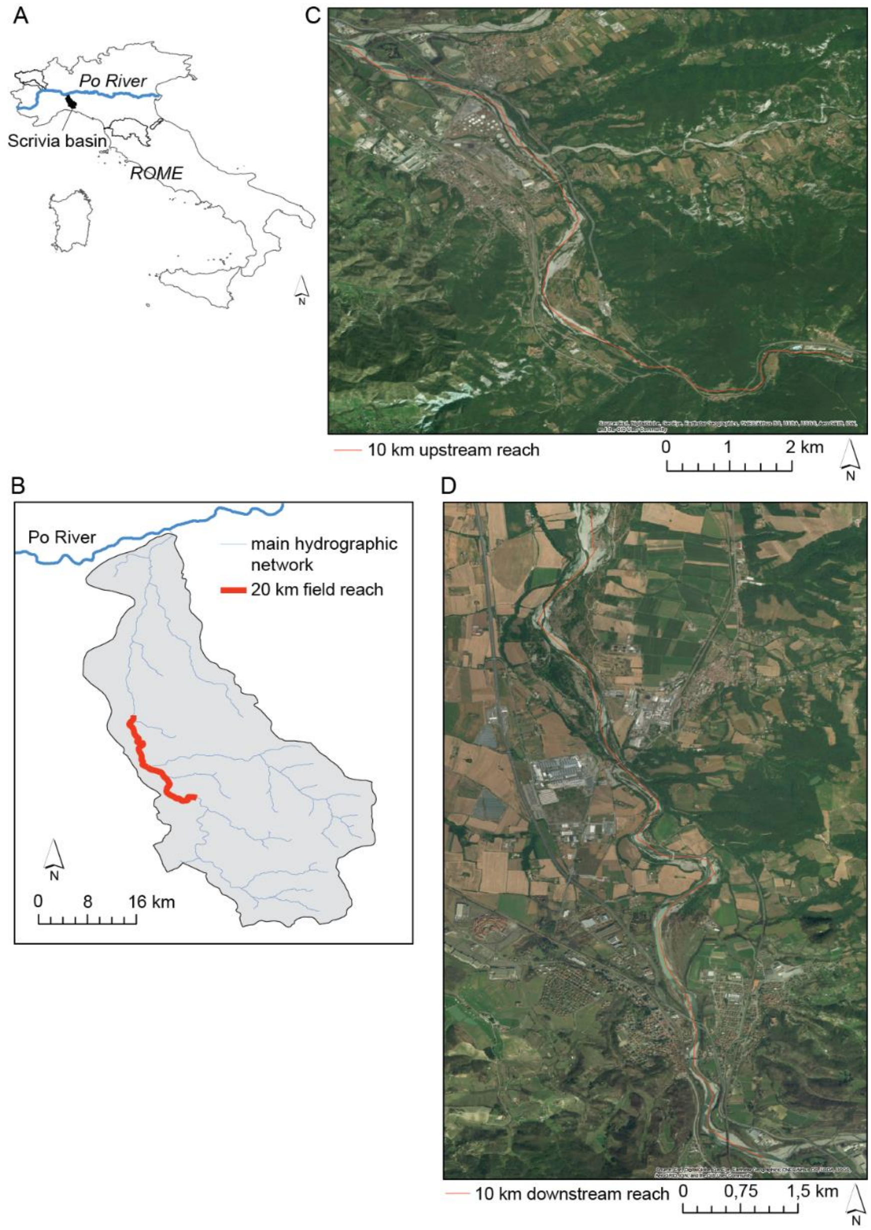


Figure 3.3.3. The Scrivia river. A, location of the river basin within Italy. B, location of the 20 km river reach selected for field validation. C and D, overview of the upstream and downstream river sections, respectively.

The Scrivia river reach is located in the mid-altitude area slightly higher than 200 m a.s.l. on average (Table 3.3.1, Figure 3.3.3). It presents mid-slope values (around 0.5%), and multi-thread channel pattern, mainly in its downstream part. It is an Apennine tributary of the Po River and its surroundings are dominated by agricultural areas.

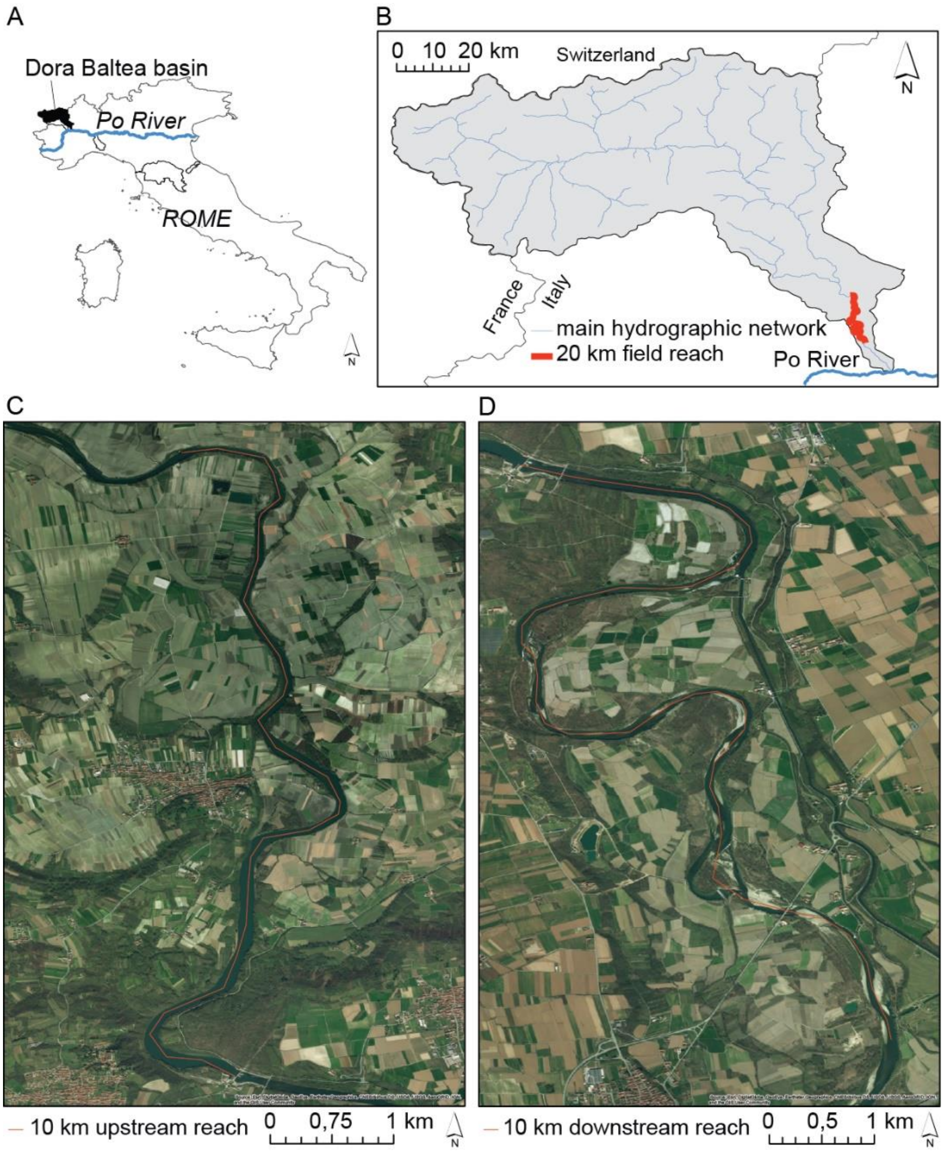


Figure 3.3.4. The Dora Baltea river. A, location of the river basin within Italy. B, location of the 20 km river reach selected for field validation. C and D, overview of the upstream and downstream river sections, respectively.

The Dora Baltea river reach is located in the upper limit of the lowland area around 200 m a.s.l. (Table 3.3.1, Figure 3.3.4). It presents low slope values (around 0.1%), and a single-thread pattern with a sinuous channel locally meandering. It is an Alpine tributary of the Po river and its surroundings are dominated by agricultural areas.

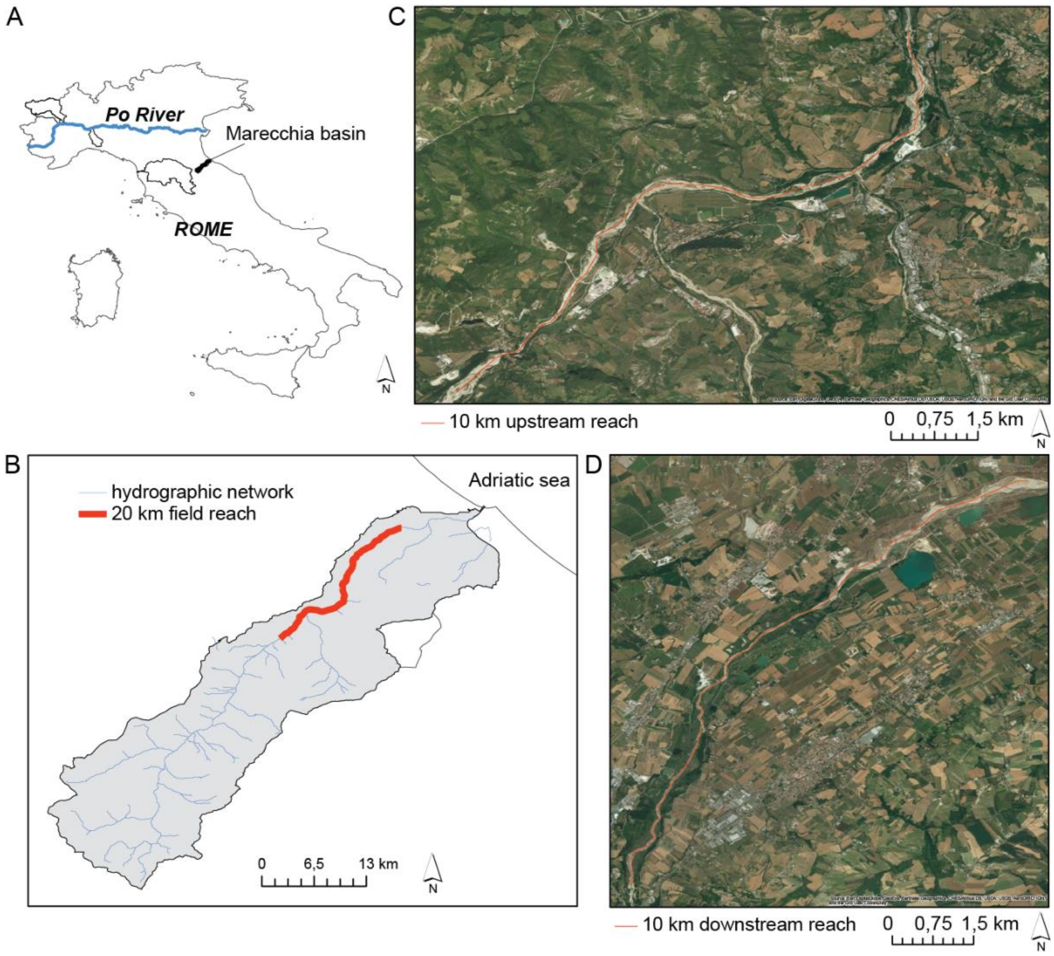


Figure 3.3.5. The Marecchia river. A, location of the river basin within Italy. B, location of the 20 km river reach selected for field validation. C and D, overview of the upstream and downstream river sections, respectively.

The Marecchia river reach is located in the lowland area around 120 m a.s.l. on average (Table 3.3.1, Figure 3.3.5). It presents mid-slope values (around 0.8 %), and multi-thread pattern, that has almost completely disappeared along the downstream reach section because of severe channel incision (above 5-7 m in average). The Marecchia river directly flows into the Adriatic Sea. Its surroundings are dominated by agricultural areas sometimes alternated by more natural forested areas.

The Arno river reach is located along the plain that crosses the city of Florence around 50 m a.s.l. (Table 3.3.1, Figure 3.3.6). It presents low slope values (around 0.1%) and single-thread pattern which is heavily maintained and channelized. The Arno directly flows into the Tirrenian Sea.

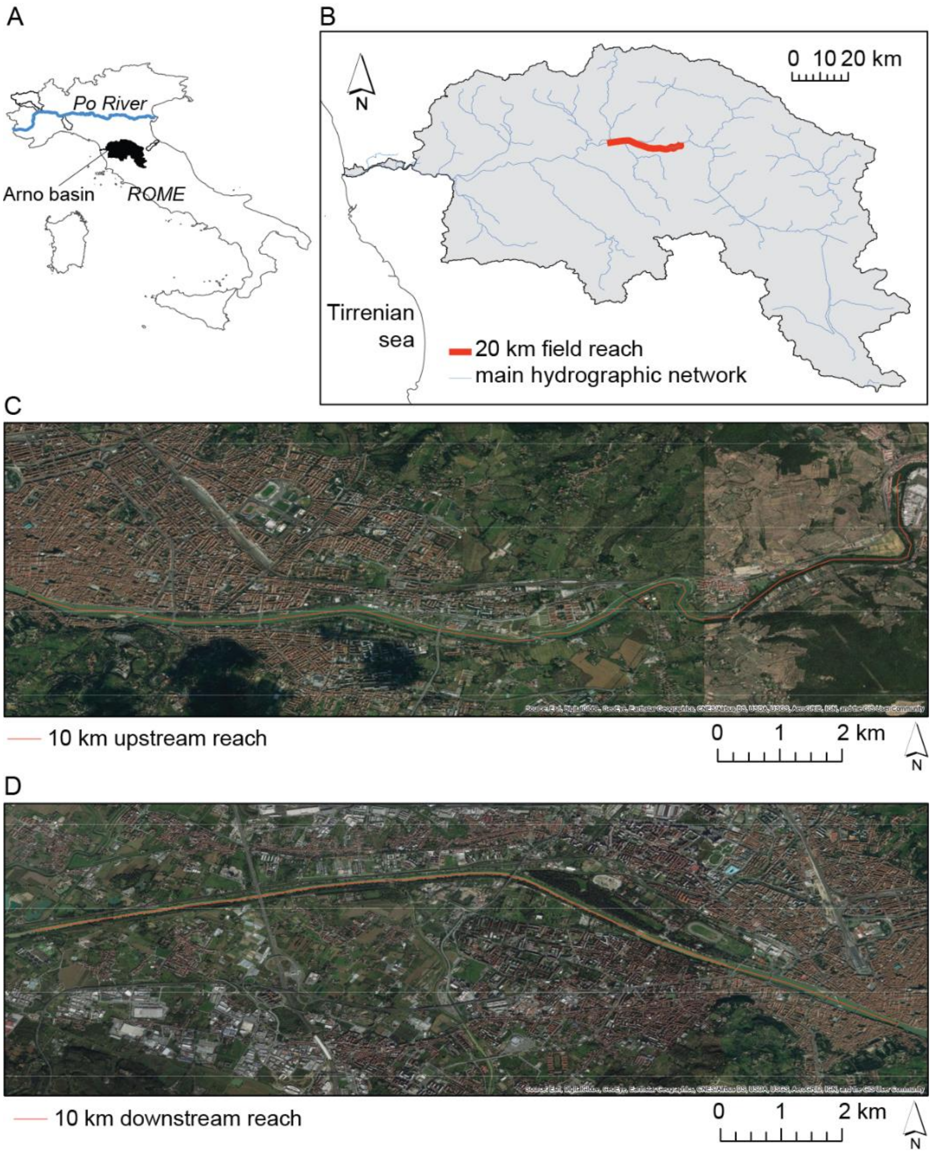


Figure 3.3.6. The Arno river. A, location of the river basin within Italy. B, location of the 20 km river reach selected for field validation. C and D, overview of the upstream and downstream river sections, respectively.

3.3.2 Results of the field work

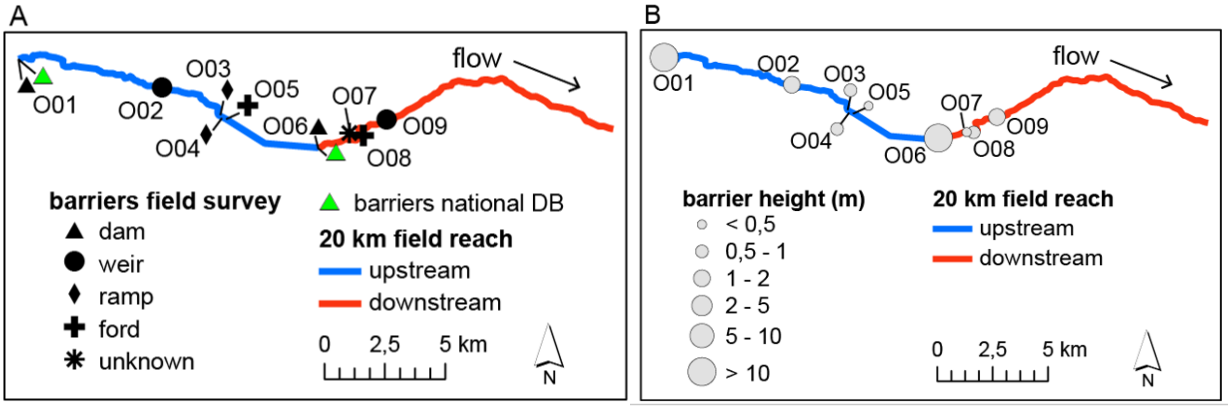
3.3.2.1 Orco river

Along the 20 km reach of the Orco river we counted 9 barriers (Table 3.3.2; Figure 3.3.7). Two of them are main dams also censed in the national database (e.g. O06; Figure 3.7.8), whereas others are mainly small structures for bed stabilization lower than 2 m (e.g. O03; Figure 3.3.8). Barrier O07 has been built mainly for bank protection (i.e. groyne), and cannot be identified by any of the classified barrier types (see Annex B), but given the large width and the effects that it may have on river processes it has been considered a barrier to longitudinal continuity as well (Figure 3.3.8). During the field survey we also discovered a new construction site about 5 km downstream the O06 dam for a new small hydropower plant.

Table 3.3.2. Results of the field survey for the Orco River. Barriers are reported in chronological order from upstream to downstream (Barrier ID). The reported variables are explained in detail in section 3.3.2.

Barrier ID	Barrier type	Barrier height	Barrier use	Barrier width	Notes
O01	Dam	> 10 m	Y	Y	Power plant; large reservoir
O02	Weir	1 – 2 m	Y	Y	Small water diversion (water supply for ski facility)
O03	Bed sill	0.5 – 1 m	Y	Y	For bed stabilization
O04	Bed sill	0.5 – 1 m	Y	Y	For bed stabilization; partially filled by sediment
O05	Ford	< 0.5 m	Y	Y	Culverts
O06	Dam	> 10 m	Y	Y	Power plant; large reservoir almost empty
O07	Unknown	< 0.5 m	Y	N	Groyne for bank and bed stabilization; width > 50% of the channel width
O08	Ford	0.5 – 1 m	Y	Y	Culverts; extensive bank protections
O09	Weir	1 – 2 m	Y	Y	Bed stabilization; large boulders; small diversion with locked gate

Figure 3.3.7. Location of the river barriers for the Orco river along the 20 km river reach. A, barrier types and comparison with the national database. B, barrier height. The barrier ID (e.g. O01), refers to Table 3.3.2.



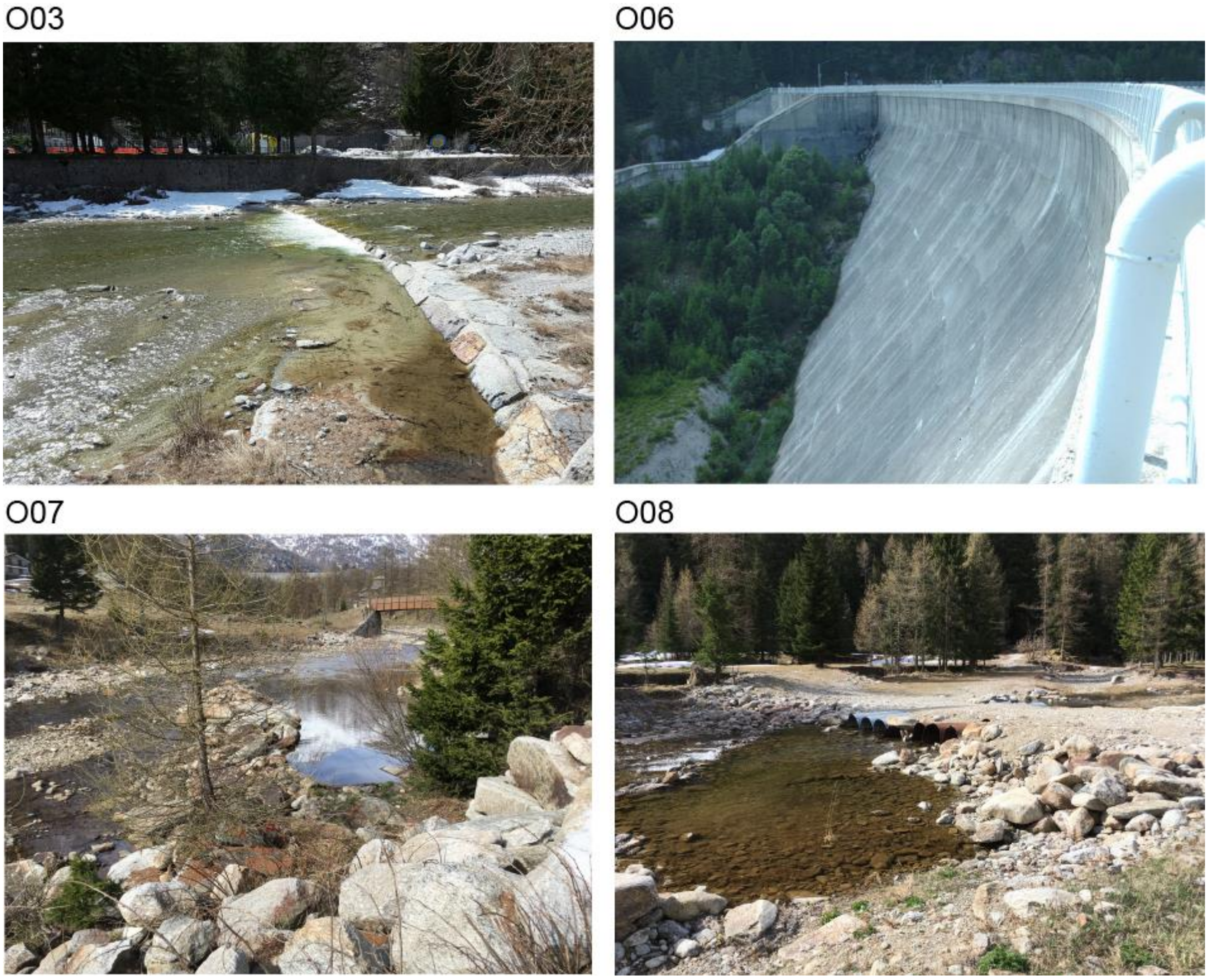


Figure 3.3.8. Some pictures of barriers from the field survey (Orco river). The barrier ID (e.g. O03) refers to Table 3.3.2). All pictures are taken from the left bank. O06 picture is taken from: http://www.panoramio.com/photo/23417519**.**

3.3.2.2 Scrivia river

Along the 20 km reach of the Scrivia river we counted 10 barriers (Table 3.3.3; Figure 3.3.9). Only one is a large dam but this is not recorded in the national database, probably because of its relatively small size (i.e. lower than 5 m and small upstream reservoir; S01; Figure 3.3.10). Amongst other barriers, two are quite high (i.e. between 2 and 5 m; S05 and S08), and the remaining are lower than 2 m, mainly aiming at bed stabilization. S09 is formed by a couple of pipes that cross all the channel and that are in contact with the channel bed, thus considered as barrier to longitudinal continuity (Figure 3.3.10).

The 2 highest barriers also present a fish pass facility (S01 and S05; Table 3.3.3; Figure 3.3.10). 4 out of 10 structures are partially damaged, demonstrating the quite high energy of the river in the surveyed section and raising questions about maintenance issues (e.g. S06; Figure 3.3.10). The channel bed also showed evidences of channel incision (e.g. exposure of bridge piles) and locally of organic or inorganic pollution (macrophytes bloom).

Table 3.3.3. Results of the field survey for the Scrivia river. Barriers are reported in chronological order from upstream to downstream (Barrier ID). The reported variables are explained in detail in section 3.3.2.

	Barrier type	Barrier height	Barrier use	Barrier width	Notes
S01	Dam	2 – 5 m	Y	Y	Power plant; fish pass; small reservoir; recent
S02	Bed sill	0.5 – 1 m	Y	N	For bed stabilization; bank and hillslope protection
S03	Weir	0.5 – 1 m	Y	Y	For bed stabilization; partially damaged
S04	Unknown	< 0.5 m	Do not know	N	Submerged bed sill
S05	Weir	2 – 5 m	Y	Y	Power plant (located 300 m downstream); fish pass
S06	Weir	1 – 2 m	Y	T	For bed stabilization; damaged
S07	Bed sill	< 0.5 m	Don’t know	T	For bed stabilization
S08	Ford	2 – 5 m	N	T	Culverts; damaged
S09	Unknown	< 0.5 m	Do not know	Y	Pipes across the channel, in contact with the channel bed
S10	Unknown	< 0.5 m	Do not know	N	Probably a bed sill

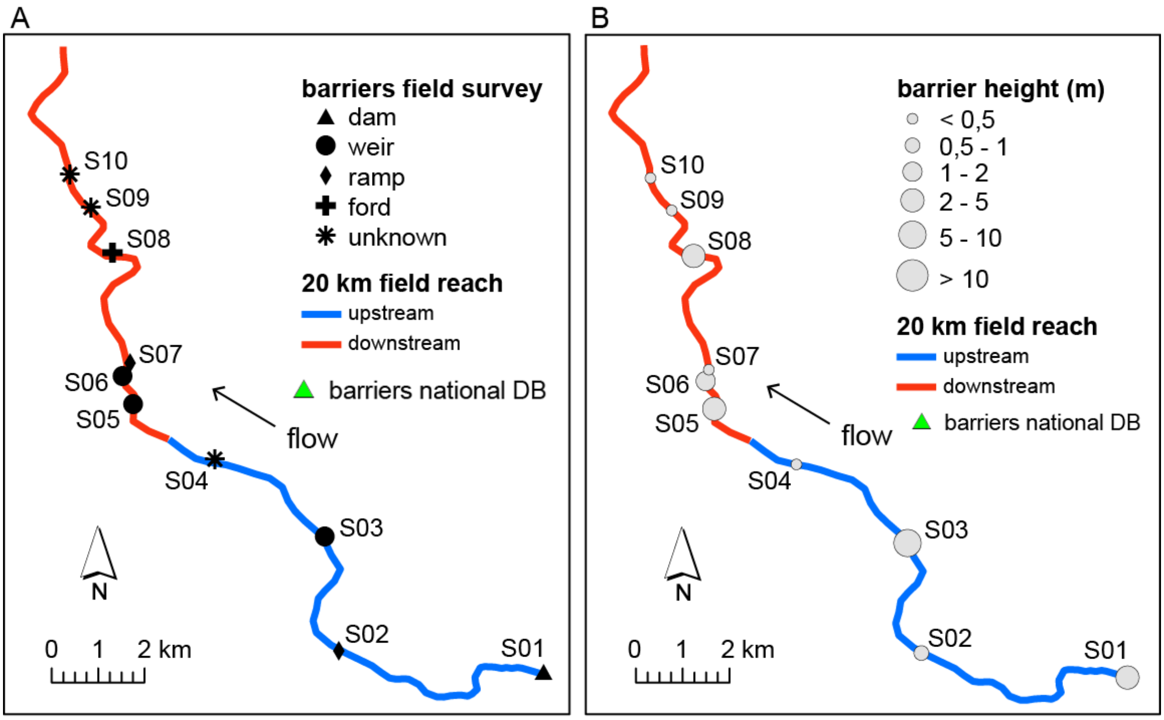


Figure 3.3.9. Location of the river barriers for the Scrivia river along the 20 km river reach. A, barrier types and comparison with the national database. B, barrier height. The barrier ID (e.g. O01), refers to Table 3.3.3.

Figure 3.3.10. Some pictures of barriers from the field survey (Scrivia river). The barrier ID (e.g. O03) refers to Table 3.3.3. Pictures S01 and S06 are taken from the right bank, whereas picture S09 from the left bank.

3.3.2.3 Dora Baltea river

Along the 20 km reach of the Dora Baltea river we counted 6 barriers (Table 3.3.4; Figure 3.3.11). Only one is a main dam that appears also in the national database (D02; Figure 3.3.11, 3.3.12). Most of the downstream barriers are abstraction weirs for agriculture that dominates extensively the land use in the area. Anyway, 4 out of 6 barriers also operate for hydro-power production. Most of these structures support bed stabilization (e.g. D05; Figure 3.3.12) and all are higher than 2 m. Most upstream barrier seems rather a bank protection structure (i.e. a groyne) but given its large width it has been considered as a barrier to longitudinal continuity as well.
2 out of 6 barriers also have a fish pass (D04 and D06; Table 3.3.4).

Table 3.3.4. Results of the field survey for the Dora Baltea river. Barriers are reported in chronological order from upstream to downstream (Barrier ID). The reported variables are explained in detail in section 3.3.2.

	Barrier type	Barrier height	Barrier use	Barrier width	Notes
D01	Unknown	< 0.5 m	Y	N	Groyne for bank and bed stabilization; width > 50% channel width
D02	Dam	5 – 10 m	Y	Y	Power plant; reservoir extends several meters upstream
D03	Weir	2 – 5 m	Y	Y	Abstraction weir and power plant; diversion
D04	Weir	2 – 5 m	Y	Y	Power plant; fish pass
D05	Weir	2 – 5 m	Y	Y	Abstraction weir; bed stabilization; linked to D06
D06	Weir	5 – 10 m	Y	Y	Abstraction weir; power plant; diversion; fish pass

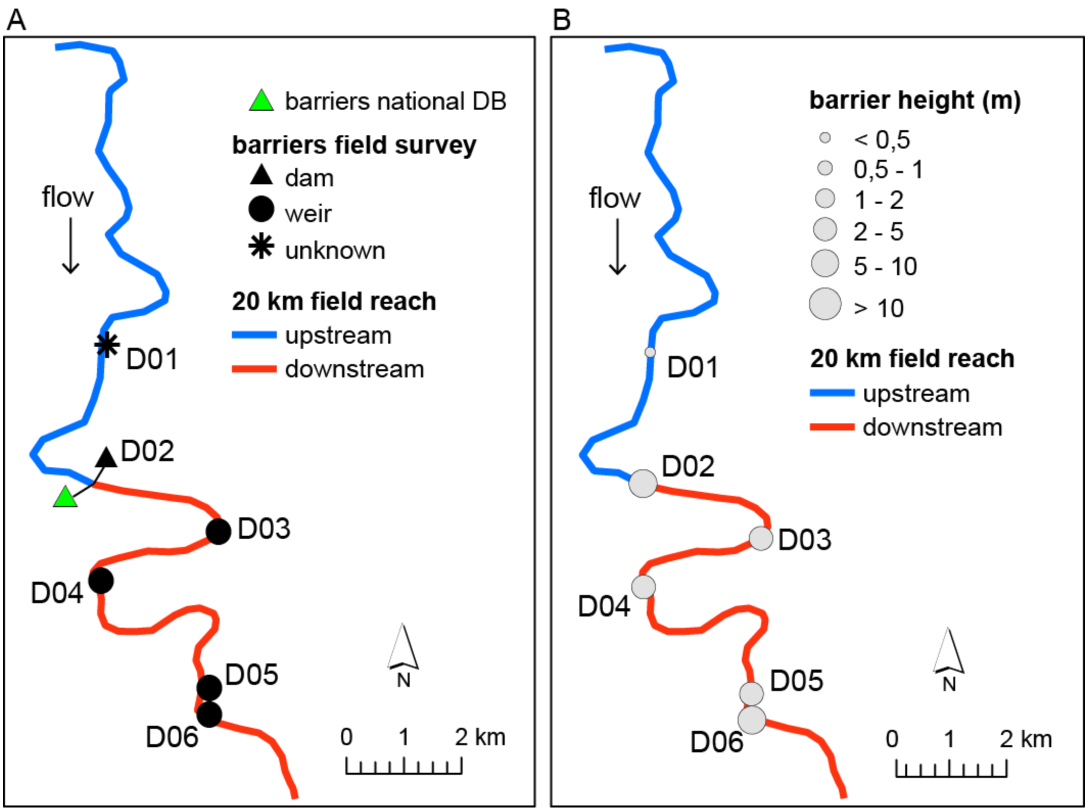


Figure 3.3.11. Location of the river barriers for the Dora Baltea river along the 20 km river reach. A, barrier types and comparison with the national database. B, barrier height. The barrier ID (e.g. O01), refers to Table 3.3.4.

Figure 3.3.12. Some pictures of barriers from the field survey (Dora Baltea river). The barrier ID (e.g. O03) refers to Table 3.3.4. All pictures are taken from the left bank.

3.3.2.4 Marecchia river

Along the 20 km reach of the Marecchia river we counted 7 barriers (Table 3.3.5; Figure 3.3.13). No large dam is present along the surveyed reach, even if we observed a quite large check dam and a high weir both between 5 and 10 m height (M03 and M06, respectively; Figure 3.3.14). Most of the barriers along the Marecchia river are bed stabilization structures, except a large and high ford in M04, that serves a mining site in the right bank in the upstream reach. M07 is an unknown structure similar to a groyne that spans almost across the entire wetted width and creates impoundment upstream (Figure 3.3.14).
Most of the downstream reach, downstream the M06 weir, is severely incised (above 10 m below the M06; Figure 3.3.14) and the riparian area is completely disconnected vertically from the river channel, displaying plant associations typical of arid areas (e.g. Scotch broom shrubs). This is certainly due by the combination of the weir in M06 and the intense sediment mining occurred within the channel bed during the 1950s-1970s, as also observed along many others Italian rivers (e.g. Surian and Rinaldi, 2003). As evidence of the sediment mining activities, along the downstream reach there are several remnant ponds, today used for fishing (Figure 3.3.15). Only for the last 3 km does the channel recover its multi-thread channel pattern.

Table 3.3.5. Results of the field survey for the Marecchia river. Barriers are reported in chronological order from upstream to downstream (Barrier ID). The reported variables are explained in detail in section 3.3.2.

	Barrier type	Barrier height	Barrier use	Barrier width	Notes
M01	Bed sill	< 0.5 m	Do not know	Y	For bed stabilization (bridge); two stages; partially submerged by sediments
M02	Weir	2 – 5 m	Y	Y	Bed stabilization; small power plant; two stages; no reservoir
M03	Weir	5 – 10 m	Y	Y	Retention check dam
M04	Ford	1 – 2 m	Y	Y	Culverts; sediment mine in right bank;
M05	Weir	1 – 2 m	N	N	Bed stabilization; damaged
M06	Weir	5 – 10 m	Y	Y	Bed stabilization; abstraction weir; small power plant; three stages; diversions; no reservoir
M07	Unknown	< 0.5 m	Y	N	Bed stabilization and bank protection; partial impoundment

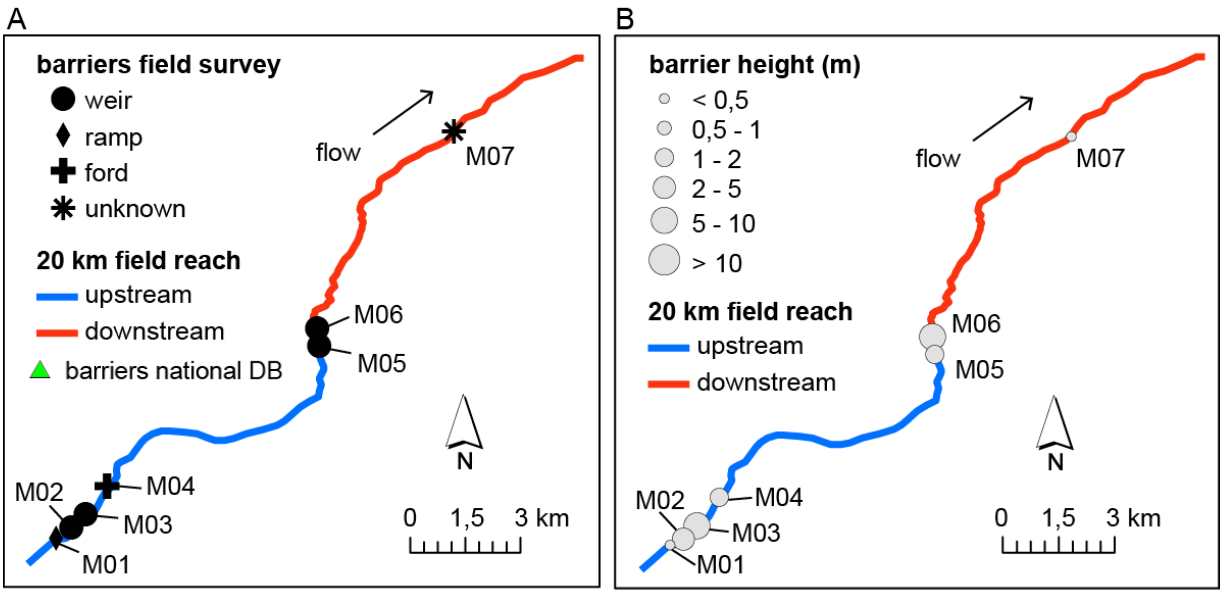


Figure 3.3.13. Location of the river barriers for the Marecchia river along the 20 km river reach. A, barrier types and comparison with the national database. B, barrier height. The barrier ID (e.g. O01), refers to Table 3.3.5.

Figure 3.3.14. Some pictures of barriers from the field survey (Marecchia river). The barrier ID (e.g. O03) refers to Table 3.3.5. Picture M03 is taken from the left bank; pictures M06 and M07 are taken from the right bank.

Figure 3.3.15. Extraction from Google Earth of a section along the 10 km downstream reach of the Marecchia river. It shows the ponds heritage of the sediment mining activity.

3.3.2.5 Arno river

Along the 20 km reach of the Arno river we counted 11 barriers (Table 3.3.6; Figure 3.3.16). No large dam above 10 m is present along the surveyed reach, but 4 out of 11 barriers are higher than 2 m and all the barrier together cause a gap in bed elevation higher than 15 m. Most barriers except one are weirs for bed stabilization (Figure 3.3.17). 3 out of 11 barriers are damaged and the ford in A07 is no longer in use (Figure 3.3.17).

Table 3.3.6. Results of the field survey for the Arno river. Barriers are reported in chronological order from upstream to downstream (Barrier ID). The reported variables are explained in detail in section 3.3.2.

	Barrier type	Barrier height	Barrier use	Barrier width	Notes
A01	Weir	1 – 2 m	Y	Y	Bed stabilization
A02	Weir	0.5 – 1	Y	Y	Bed stabilization; linked to A03
A03	Weir	1 – 2 m	Y	Y	Bed stabilization; linked to A02
A04	Weir	1 – 2 m	Do not know	Y	Bed stabilization; damaged
A05	Weir	2 – 5 m	Do not know	Y	Bed stabilization; damaged
A06	Weir	5 – 10 m	Y	Y	Bed stabilization; two stages (3 - 4 m each); ex water mill
A07	Ford	0.5 -1 m	N	N	Boulder and concrete; damaged
A08	Weir	1 – 2 m	Y	Y	Bed stabilization; Florence
A09	Weir	< 0.5 m	Y	Y	Bed stabilization; Florence (below a bridge)
A10	Weir	2 – 5 m	Y	Y	Bed stabilization; Florence
A11	Weir	5 – 10 m	Y	Y	Bed stabilization; two stages; Florence

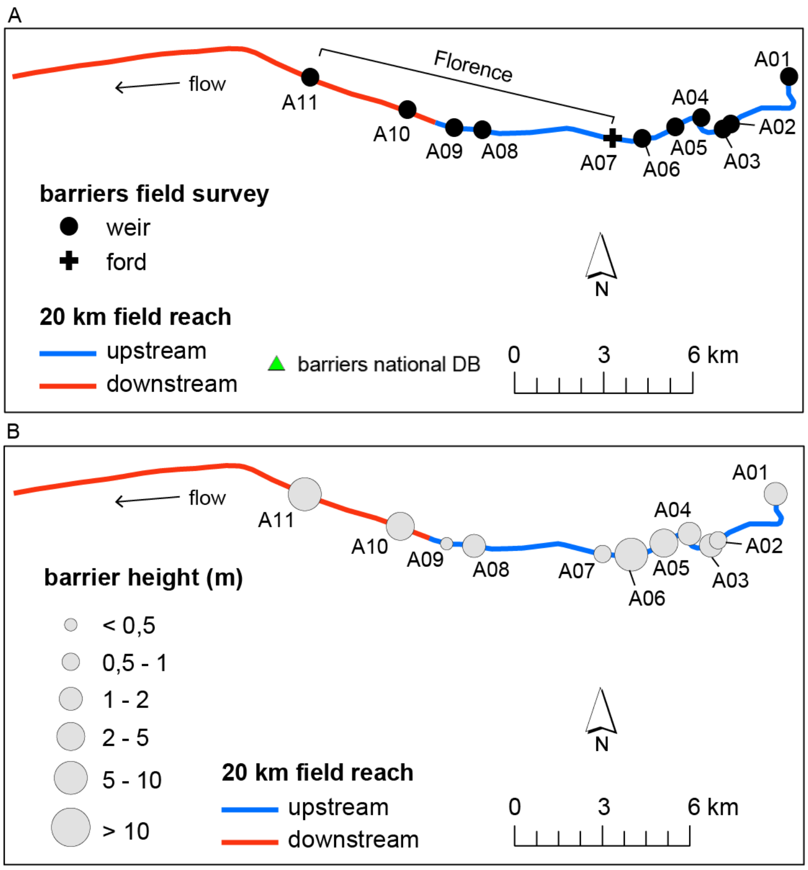


Figure 3.3.16. Location of the river barriers for the Arno river along the 20 km river reach. A, barrier types and comparison with the national database. B, barrier height. The barrier ID (e.g. O01), refers to Table 3.3.6.

Figure 3.3.17. Some pictures of barriers from the field survey (Arno river). The barrier ID (e.g. O03) refers to Table 3.3.6. Picture M03 is taken from the left bank; pictures M06 and M07 are taken from the right bank. All pictures are taken from the right bank.

3.3.3 Summary of field results and comparison with existing databases

During the field work we observed 43 barriers for a total of 100 km of river length surveyed across 5 different rivers.

The most common barrier type is weir, with 23 observations along all river reaches, but mainly located along the Arno river (Figure 3.3.18). In average these are quite small barriers (2.9 m) with most structures in height classes 3 and 4 (i.e. below 5 m). Fords and bed sills are present 5 times each where the Dora Baltea does not display any of these structures and bed sills are mainly present along reaches with higher slope values (Table 3.3.1; Orco, Scrivia and Marecchia). In general these are small structures about 1 m in average. Only 4 major dams have been observed and these are located only along tributaries of the Po river (Orco, Dora Baltea and Scrivia). Dams are highest structures falling in height classes 4 to 6 (i.e. 8.5 m in average). The other 6 barriers do not belong to any of the types above or it was difficult to determine the type for practical reasons (e.g. S09 and S10, respectively; see section 3.4.2.2). In 3 out of the 6 cases these are groynes that span the most part of channel width and thus has been considered as barriers to longitudinal continuity, along the Orco, the Scrivia and the Dora Baltea river reaches. These are the smallest structures all falling in height class 1 (on average 0.2 m).

Only 4 barriers present fish pass facilities, two along the Scrivia and two along the Dora Baltea river reaches.

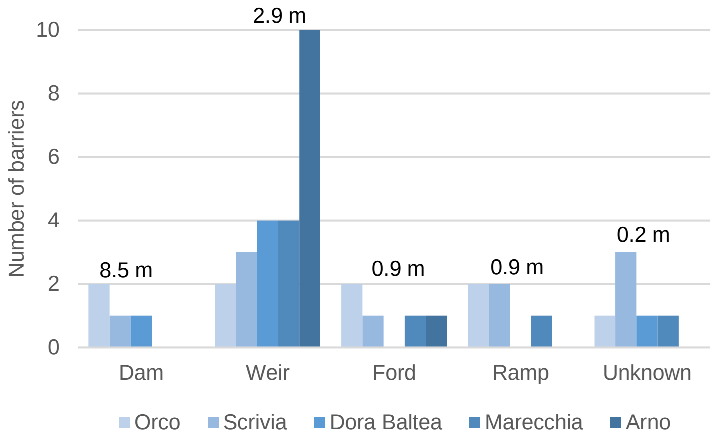


Figure 3.3.18. Distribution of the number of barriers between barrier types and river reaches. The mean barrier height (m) per class of barrier type is also displayed.

As expected, most barriers are located along a wide range of altitudes and slopes, whereas large dams (i.e. above 10 m) are mainly located at high altitudes and slopes (Figure 3.3.19). When looking at the barrier uses and purposes, 3 barriers out of 43 are no longer in use and other 6 are probably not in use as well (e.g. damaged structures), and all these are located along the Scrivia, Marecchia and Arno river reaches. Most of the barriers support bed stabilization, where barriers are 2 m height in average (Figure 3.3.20). This is the case for the 90%, the 85% and the 60% of barriers along the Arno, Marecchia and Scrivia river reaches, respectively. But also the 44% and the 16% of barriers along the Orco and the Dora Baltea river reaches support bed stabilization.

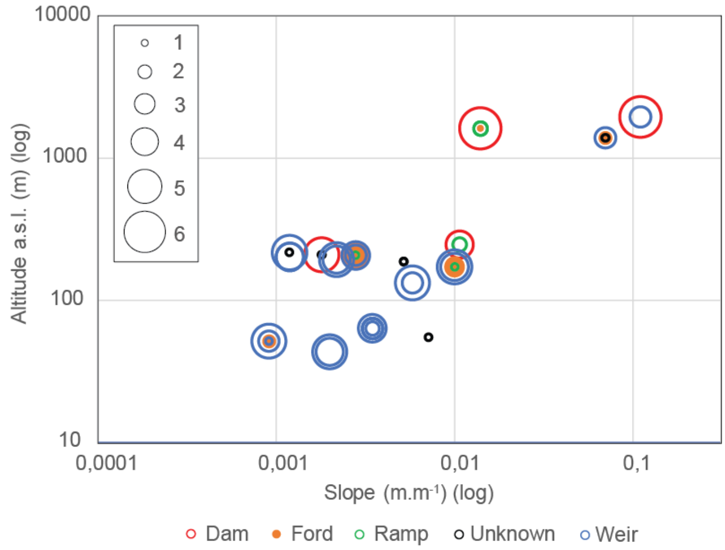


Figure 3.3.19. Distribution of the number of barriers between barrier types and river reaches. The mean barrier height (m) per class of barrier type is also displayed.

Barriers for hydro-electricity generation are generally higher than other barriers (6,5 m in average) and are mainly located along the rivers of the Po basin, representing the 22%, 20% and 33% of barriers in the Orco, Scrivia and Dora Baltea river reaches, respectively. Water supply is the main use along the Dora Baltea river reach (50%), where barriers are in average 3.5 m height. Crossing structures are in general small structures lower than 1 m and are quite widespread (i.e. at least 1 structure per river reach but the Dora Baltea).

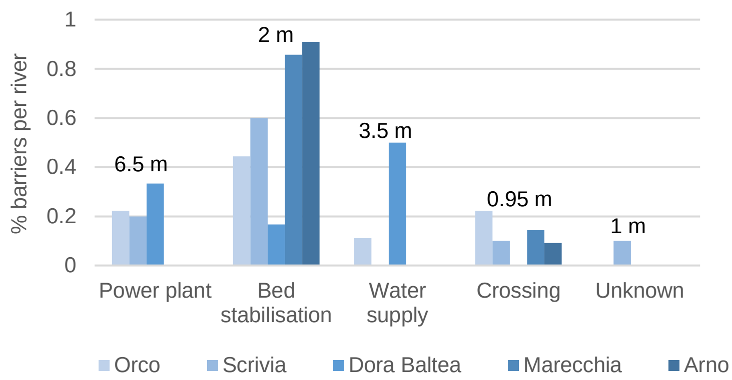


Figure 3.3.20. Percentage of barriers per rivers according to the main use. The mean barrier height (m) per category of use is also displayed.

The field survey has demonstrated that the surveyed river reaches are currently impacted by several types of barriers (Figures 3.3.18, 3.3.19, 3.3.20) and the density values of these structures per river kilometer is comparable between rivers of different type (Table 3.3.7). When comparing the barrier density between field survey results and the national database it emerges that the national database, which records only main dams, is underestimating barrier presence along the surveyed river reaches (Table 3.3.7). In particular, for most reaches the density of barriers is 0 or close to 0 when considering the national database, whereas it is almost 1 barrier each 2 km when looking at the results of the field validation.

The density of barriers for the national database is in general low also at the entire network scale for all river basins.

Table 3.3.7. Comparisons of barrier number and density (n/km) between the field survey and the national database. NF, number of barriers after the field work; NN, number of barriers in the national database; DF, density of barriers after the field work; DN, density of barriers in the national database. The number and density of barriers in the national database along the entire river network (whole basin) is also reported for comparison.

	NF	NN	DF	DN	NN whole basin	DN whole basin
Orco	9	2	0.45	0.1	6	0.01
Scrivia	10	0	0.5	0	2	0.004
Dora Baltea	6	1	0.3	0.05	9	0.003
Marecchia	7	0	0.35	0	0	0
Arno	11	0	0.35	0	18	0.004

For the Piemonte region and for the Arno basin we also collated for comparison some databases at the regional level that were freely accessible from the web.

For the Piemonte region, we had access to two different databases (Figure 3.3.21):
(1) The regional database that includes main river barriers whose management depends by the regional authority and that includes several typologies of dams and weirs as well as reservoirs mainly with hydraulic and hydrologic purposes (flood protection or water supply; http://www.sistemapiemonte.it/cms/pa/territorio-edilizia-e-opere-pubbliche/servizi/718-catasto-sbarramenti-pa/);
(2) The regional database on flood and soil defenses, that includes all minor structures for bed stabilization, bank and hills protections etc. (http://www.regione.piemonte.it/difesasuolo/cms/pianificazione/sicod.html).

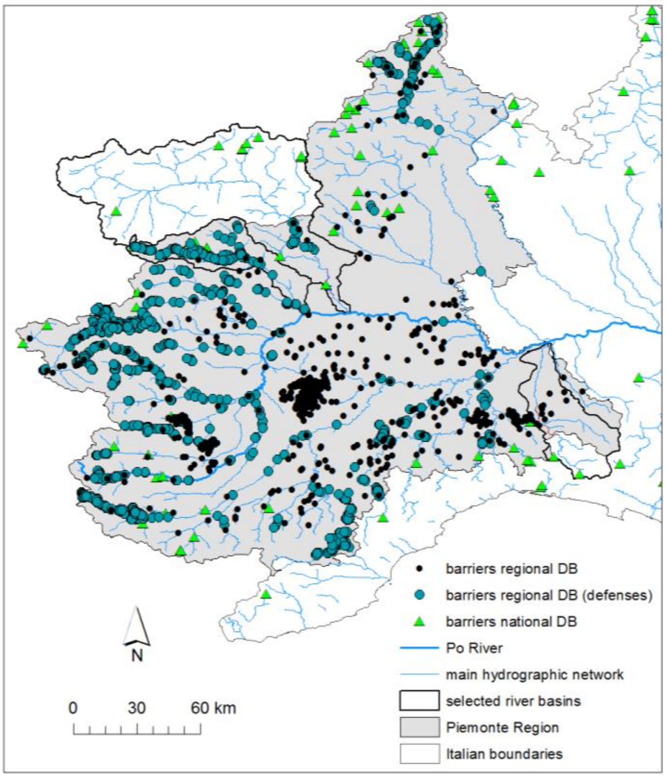


Figure 3.3.21. Comparison between the national database and the regional ones for the Piemonte Region.

For the Arno basin, we had access to three different databases (Figures 3.3.22, 3.3.23):
(1) The regional database on flood and soil defenses, that includes all minor structures for bed stabilization, bank and hills protections etc. (http://www.regione.toscana.it/-/censimento-delle-opere-idrauliche-e-di-bonifica);
(2) The database of the northern apennine hydrographic district, which includes all river crossing structures (http://www.adbarno.it/pagine_sito_opendata/gds_md_scheda_completa.php?id_ds=2103);
(3) The database of the Arno river basin, which includes weirs and hydraulic-forestry installation for flood, soil and hills defense (http://www.adbarno.it/pagine_sito_opendata/gds_md_scheda_ridotta.php?id_ds=1540).

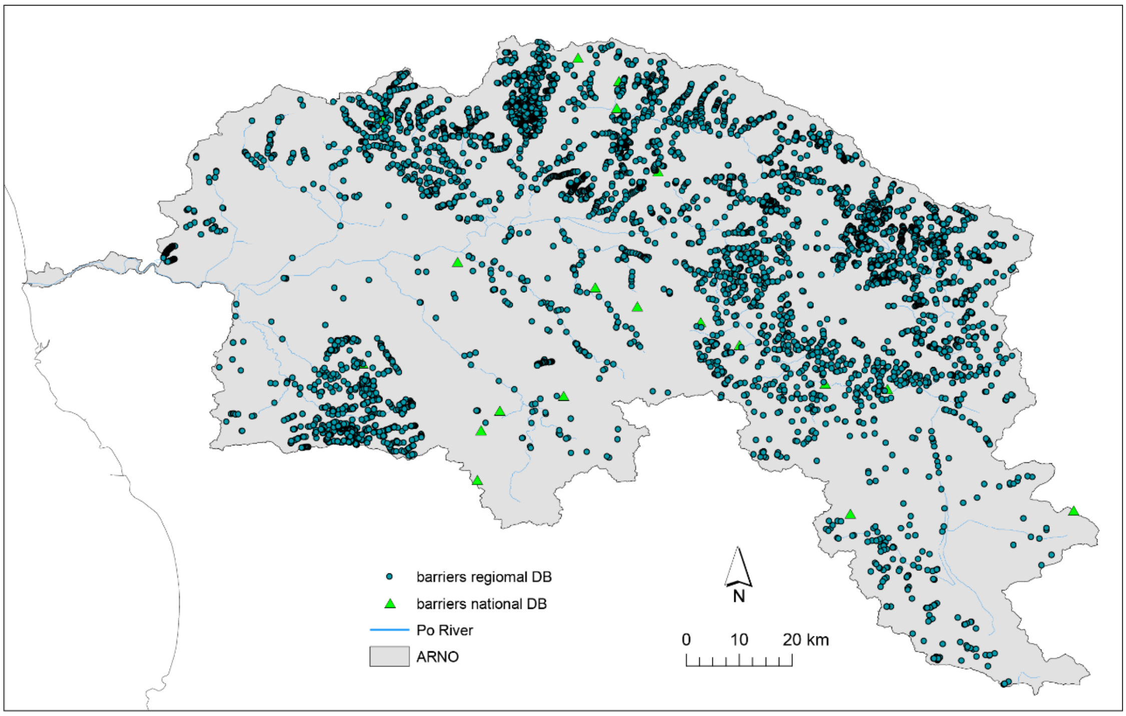


Figure 3.3.22. Comparison between the national and the regional database for the Arno river basin.

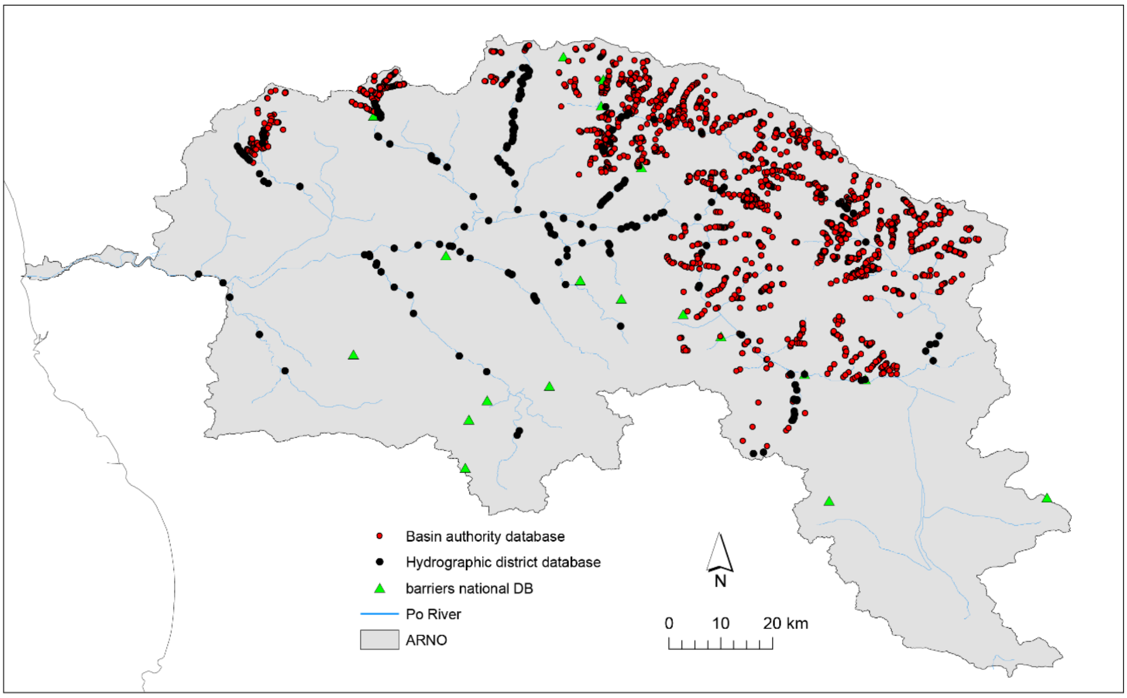


Figure 3.3.23. Comparison between the national database and the databases at the river basin and northern hydrographic district levels for the Arno river basin.

Both for the Piemonte Region and the Arno river basin, the different databases are complementary because they have been developed for different purposes, hence providing a more general picture of presence and location of barriers in the respective areas. Anyway, when comparing all these databases with our field validation work it emerges that (Figures 3.3.24, 3.3.25):

- Both for the Scrivia and the Dora Baltea none of the databases at the regional level record the barriers that has been observed during the field work (except the dam of national interest along the Dora Baltea, D03; see section 3.3.2.3);
- For the Orco river, two of the barriers observed during the field work are also displayed in the regional database on flood and soil defenses (i.e. the weir in O02 and the ford in O08; see section 3.3.2.1). Two additional fords are also recorded in this regional database that has not been observed during the field work (one in the upstream reach after O02 and one in the downstream reach before O07);
- For the Arno river, almost all barriers are recorded in the database from the northern hydrographic district except the ford in A07 and the weir in A09 (see section 3.3.2.5).

It is worth noting that, even if it has not been reported in Figures 3.3.24 and 3.3.25, these additional databases also contain detailed information on barrier types as well as additional characteristics different from one database to another.

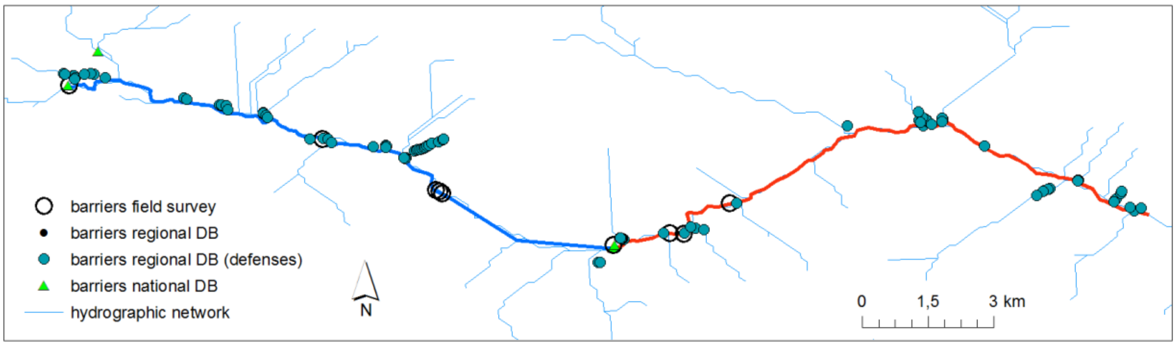


Figure 3.3.24. Comparison between the field results and all the available databases along the 20 km of the Orco river reach. Most of the barriers in the regional databases on soil and flood defences are located along small tributaries.

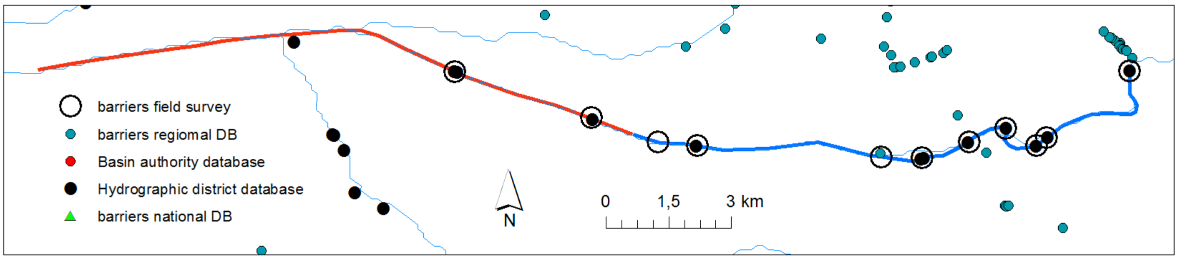


Figure 3.3.25. Comparison between the field results and all the available databases along the 20 km of the Arno river reach. Most of the barriers in the regional databases are located along small tributaries.

4 CONCLUSIONS & DISCUSSION

Barriers to river longitudinal continuity are widely recognised having a critical impact on freshwater ecosystems and ecosystem services (Petts and Gurnell 2005; McCartney 2009; Yn et al. 2014).

The preliminary analysis on collated data on 13 countries combined with the field validation work applied in Italy generated some relevant findings concerning our present knowledge about the status of river continuity both at the pan-European and at the local scale. These points are here discussed and some recommendations are described for the adaptive management of the information on river barriers in a consistent manner across Europe. Finally, the next steps in AMBER toward the generation of the first pan-European ATLAS on stream barriers are briefly described.

4.1 Summary of key points

4.1.1 Barrier density

While some countries seem up-to-date in terms of monitoring of river barriers at the national scale (e.g. France, Netherland), others such as Italy are still do not have a consistent overview of barrier density at the national scale. This emerges clearly when comparing the density of barriers per river kilometer from national data bases with the field validation results. Indeed, the values of barrier density (barriers per kilometer) observed in field validation in Italy (0.39) are comparable to values found in high density national databases across Europe: France (0.48), England (0.51), Wales (0.57), Denmark (0.47), Switzerland (0.30), Northern Ireland (0.43) and the Netherlands (0.83). In the Italian national database, where only main dams are recorded consistently, the density is considerably lower (0.0038), compared to France (0.0023) when examining barriers above 10 meters. The Italian national database has a density of on average around one barrier every two kilometers however, field validation studies in Italy and other European countries is likely to be a much better reflect the real barriers density in European rivers, especially for smaller barriers.

The Italian regional databases that had information on smaller barriers was shown to be difficult to use in validation as it is scattered across few regions or provincial areas and has been sampled with different protocols. This problem of using more intense localised barrier studies to validate national databases is also likely to occur in other countries such as Spain.

4.1.2 Barrier height

Barrier height is a key parameter of barrier monitoring (see Table 2.2.1 and also Table A1 of D1.1 Part B) since it provides a basic physical information on the amount of impact that a barrier may cause on river longitudinal continuity both for biological and physical processes. Despite being an easily collected parameter, particularly as height classes, it is missing in a significant amount of data samples. Currently, this information is not consistently reported in most databases (e.g. France, Poland, and Sweden) and completely missing in others (e.g. Netherland and Ireland). However, our results show that, when height information is available, almost 90% of the impacts on river continuity is due to small-medium barriers between 1-5 m height. This is consistent with the results of the field work carried out in Italy, where small-medium barriers below 5 m represent 80% of observed barriers, with only 5% of barriers being higher than 10 m.

4.1.3 Barrier types

There being 293 different types of barriers defined within the thirteen databases analysed highlights the need to define a much smaller and clearly defined number of barrier types which can be adopted consistently across Europe (see section 4.3 below).

Given that databases have been built for different purposes and rarely to specifically address river continuity issues, some barrier types may not be relevant for the ATLAS purposes. For example, 'road crossing' could be a 'ford' acting as a barrier to river continuity or simply a 'bridge' not in contact with the channel bed. The integration of regional or local databases that have been built for specific purposes (e.g. flood and soil defense), and the field validation task, will assist with the discrimination of relevant barrier types for the assessment of longitudinal continuity in rivers.

4.2 Recommendations for adaptive management of databases on river barriers

Our findings show that, despite river continuity being a requirement of WFD reporting within RBMPs, suitable national databases on river barriers to assess such fragmentation do not exist. Some countries have high density databases (e.g. France, England, Sweden etc.), which often lack consistent information on key parameters, such as barrier height or presence or absence of fish passage, which are necessary to provide a realistic assessment of the potential impact of the barrier on ecological, hydrological and geomorphological processes. Our study showed the importance of building a barrier ATLAS where information on heights is consistently recorded as this is a key variable in assessing river connectivity and is easy to monitor. Also, if validation supports the national data indicating a variable occurance of fish passes along most European rivers, a significantly different assessment of ecological continuity would result than from monitoring just barrier data alone. It is thus a priority for future monitoring campaigns that the presence or not of a fish passage is recorded, and this information must be a key parameter for the ATLAS. Each country should revise its monitoring protocol to include information on height and fish pass since these are critical and cost-effect parameters to be monitored for assessing the potential impacts of river barriers.

In countries such as Italy, Spain and Poland, where many barrier types are monitored but they lack consistent databases at the national scale, should make efforts at the national administration level to establish a consistent monitor network aiming at properly assessing the degree of river connectivity and building a suitable national database which aggregates all existing local information in a consistent way. Indeed, the validation exercise described in 3.3 highlighted how the integration of regional and local existing databases at the national level could provide a more realistic picture of the presence of barriers as well as a better characterization.

It is also necessary to provide general guidelines at European level so to guarantee consistency and comparability across European country databases. In this respect, specific barrier type categories targeting the assessment of river longitudinal connectivity should be defined. The current inconsistency and wide variety of categories (293 types) present in European databases analyzed are not the suitable for such a purpose.

Finally, the year of construction is missing from most of the databases. This information, or in case it is not available, qualitative assessment if the structure is still functioning or not, would be very useful. Such information is relevant to estimate when rehabilitation and management effort (and thus cost) is expended in maintaining or repairing older barriers. Information will also need to be collected on whether a barrier structure has been removed, since it is becoming an increasingly common practice.

4.3 The AMBER contribution

The AMBER objectives address some of the challenges and recommendations described in section 4.2. First, during the next months the AMBER consortium will work to define a manageable number of barrier types (see section Annex A) which can be adopted consistently across Europe for river continuity assessment. As well as providing useful information to assess the potential impacts of the barriers on the fluvial system, and will try to be applicable with a minimum effort to already existing national and regional databases. For these reasons, we are developing a reasonable (e.g. five to ten) definitions of barrier types (see also section 2.2 and Annex B). This task is done accordingly to the stream barrier monitoring APP, currently under development in WP5, so to harmonize existing official information with crowd-sourced one, which will be collated in the near future within AMBER. In case of countries where information on barrier type is not reported there are two options. It will be added if the knowledge is available: for instance, in Italy we know that the national databases includes only dams. Whereas, barrier type information will be missing in those countries where different types of barriers are recorded but there is no labelling of their type, see for instance so far the cases of Northern Ireland.

The validation phase which is being carried out more extensively in other European countries during the summer of 2017 will help in the interpretation and examining the consistency of the information collated from national and regional databases e.g. recording barrier types in Poland, barrier heights in the Netherlands and both for Northern Ireland. By relating national and regional data bases with AMBER field validation data it should be possible to generate correction factors on barrier density to get better estimates of national and pan-European barrier numbers, as well as assist in getting a truer picture of river fragmentation. Once we have a more complete, validated and reliable picture at the pan-European scale we should also be able to explain differences in barrier density, type or height according to geographic or socio-economic factors. For instance, explaining the high density of barriers in the Netherlands versus the low density in Sweden; or the distribution of barriers higher than 10 m along mountain areas (section 2.4).

The AMBER consortium will continue the process of database compilation for non-AMBER countries (group B and C; see section 2.2) during the following months.

4.4 Concluding remarks

The main difficulties encountered during the data collection can be summarised as follows:

- In some countries, river barriers are managed by many different organizations (e.g. Italy or Spain);
- The information is not always accessible and public (e.g. Germany);
- The concept of river connectivity is poorly accounted for in existing databases and in their recorded variables;

- When multiple databases exist, information on river barriers is fragmentary, and sometime redundant (e.g. in Switzerland), and the data is often built on different data standards due to varying database purposes.

Despite this, our results showed that the AMBER project should give a much better overview of medium and large barriers (higher than 5-10 m). Unfortunately the spatial coverage of the AMBER ATLAS will probably be limited due to the absence of currently available data on smaller barriers in many countries (e.g. Italy). However, field validation within AMBER may go some way to enabling extrapolation from the current databases to get better estimates of barrier numbers. Also, citizen science (using the AMBER app) will contribute to filling data gaps at the pan-European scale. These three aspects should provide much more realistic estimates of river fragmentation at the national and pan-European scale.

The work described in this report highlights the need for a specific strategy, including country specific plans of action, for consistent monitoring of river connectivity at the pan-European scale. AMBER results are creating the basis for a shared vision and common pan-European standards on stream barriers surveys for national monitoring programs (see main findings of this deliverable and D1.1 Part B), and for more targeted and detailed barrier assessment frameworks (see D1.1 Part A). In particular, this report has highlighted the need for building specific national databases within each Member State for the purpose of assessing river (longitudinal) connectivity. This is important since connectivity is extremely important in biological and physical processes. For some countries, this would require a small effort (i.e. to update the survey protocol including key variables which they currently miss), whereas for others it would require a much greater effort i.e. to combine datasets from different spatial sources and plan a national monitoring program of river barriers and associated key parameters. However, these efforts are already required under the WFD in order to properly implement the RBMP. To this aim the evidence and findings provided in this report create a state-of-the-art framework for barrier monitoring at the national scale and informs the design of survey protocols for stream barrier monitoring at this scale.

5 REFERENCES

Kondolf G. (1997). PROFILE: Hungry Water: Effects of Dams and Gravel Mining on River Channels. Environmental Management 21:533–51.

Lehner B., Liermann C.R., Revenga C., et al. (2011) Global Reservoir and Dam (GRanD) database.

McCartney M. (2009). Living with dams: managing the environmental impacts. Water Policy 11:121–139.

Petts G.E., Gurnell A.M. (2005). Dams and geomorphology: Research progress and future directions. Geomorphology 71:27–47.

Petts G.E., Gurnell A. (2013). Hydrogeomorphic effects of reservoirs, dams and diversions. In: Shroder J. (Editor in chief), James L.A., Harden C.P., Clague J.J. (Eds.), Treatise on Geomorphology. Academic Press, San Diego, CA, vol. 13, Geomorphology of Human Disturbances, Climate Change, and Natural Hazards, pp. 96–114.

Poff N.L., Hart D.D. (2002). How Dams Vary and Why It Matters for the Emerging Science of Dam Removal. Bioscience 52:659–668.

Rinaldi M., Gurnell A.M., González del Tánago M., Bussettini M., Hendriks D. (2016). Classification of river morphology and hydrology to support management and restoration. Aquatic Sciences: research across boundaries 78: 17-33.

Surian N., Rinaldi M. (2003). Morphological response to river engineering and management in alluvial channels in Italy. Geomorphology 50:307-326.

Wilder N., Larsen A., Lungershausen U. (2014). Historical impact of dams and weirs on the fluvial system in the low order rivers of central Europe. In: EGU General Assembly Conference Abstracts. Geophysical Research Abstracts, EGU General Assembly 2014, p. 4482.

Yin X.-A., Yang Z.-F., Petts G.E., Kondolf G.M. (2014). A reservoir operating method for riverine ecosystem protection, reservoir sedimentation control and water supply. Journal of Hydrology 512:379–387.

ANNEX A: TECHNICAL STRUCTURE OF THE ATLAS

A.1 Introduction

In order to build a first pan-European ATLAS on stream barriers, existing data from different sources must be combined and merged into a single dataset. The main task requires to **homogenize** data in a common ATLAS format so that they can be merged in a centralized and **consolidated database**.

This process aims at creating a repository that contains all the information included in each of the source databases and whose format and content may be updated in time with the availability of new information. A predefined number of key variables useful for barrier reporting, according to Table A1 D1.1 Part B (see also Table 2.2.1 of this report) will be extracted from each of the source databases and merged together, creating the main output (table) of the AMBER ATLAS which allows data to be reported consistently at Pan-European scale.

The following section describes the technical tasks undertaken to manage and integrate different databases, and the technical choices that have been made in order to merge the data. The overall process that led to the development of the ATLAS is described and its implementation is displayed through practical examples.

A.2 The AMBER ATLAS: a relational database

Given that the collated data are of different origins, of different languages, and that both local and national administrations manage different and specific issues on river continuity, consolidation of data at the pan-European scale cannot be merely a task that merges existing databases.

For AMBER purposes, we decided to organize the information in two levels (see also D1.1 Part B): a basic level storing all the source information and a simpler level displaying only most common and relevant variables allowing for analysis at the pan-European level (i.e. the key variables of Table 2.2.1). These key variables allow to organize data as follows:

- database-related data (e.g. country, source ID);
- data about barriers (e.g. barrier height, geographical coordinates, use);
- typology; the types of barriers.

This means that the structure of the ATLAS cannot be limited to a single table and the data processing cannot be limited to a simple export-import of raw data.

For the scope of the ATLAS it has been decided to adopt a **relational database** system which despite its complexity offers much more advanced functionality and efficiency compared to a flat database system (e.g. comma-delimited text files or Excel spreadsheets). A relational database can be considered as a container made up of a set of tables that store the data. Instead of having the data stored in the same file, the data is distributed in several tables that can be linked together by key identifiers (e.g. a unique ID). These key values make it possible to relate records in one table to another in a parent-child relationship or dependency. The management of the ATLAS data will be done using a rDBMS (relational Database Management System; i.e. the software server that manages databases) allowing the management and access of the data for example through a GIS server. Relational databases require a server that stores and interprets the metadata defining the content. Users can only access data through this software service, often hosted by a remote physical server. Common relational database servers would include Microsoft SQL Server, Oracle Database Server and MySQL and relative editors. For convenience, the ATLAS will be managed with an SQL Server. A free version of SQL Server (Express edition) is available and can be downloaded on the web.

Data from the different countries have been received as flat files (mainly Excel files). In order to obtain a consolidated and relational database from single flat local databases we implemented an **ETL process** (Extraction–Transformation–Loading). This process allows for the extraction of data from several sources, its polishing, customization, reformatting, integration, and insertion into a data warehouse.

A.2.1 The ETL process

The process consists of 3 steps:

- **Step 1: Extraction of data** (see A.2.1.1). It consists of analyzing the source files and then loading them into memory with the correct encoding and finally saving them in a specific SQL (Structured Query Language) database without taking into account the attributes required by the ATLAS. All raw data is therefore stored in SQL databases and available for future use.
- **Step 2: Transformation of data** (see A.2.1.2). The objective of the transformation is to modify the raw data, i.e. to homogenize them and format them for the needs of the ATLAS. The data can be filtered or calculated if necessary according to the source before the consolidation.
- **Step 3: Load** (see A.2.1.3). The loading operation first corresponds to the creation of the main database "AMBER_ATLAS" and then to the import of the data created in Step 2 of the ETL.

If the first 2 steps of the ETL can be performed on multiple sites, the final step must be done in the same physical database to avoid redundancy problems and ensure that everyone is working on the same dataset.

At the end of Step 3, all the local data have been homogeneized and centralized in the same database and are ready for analysis.

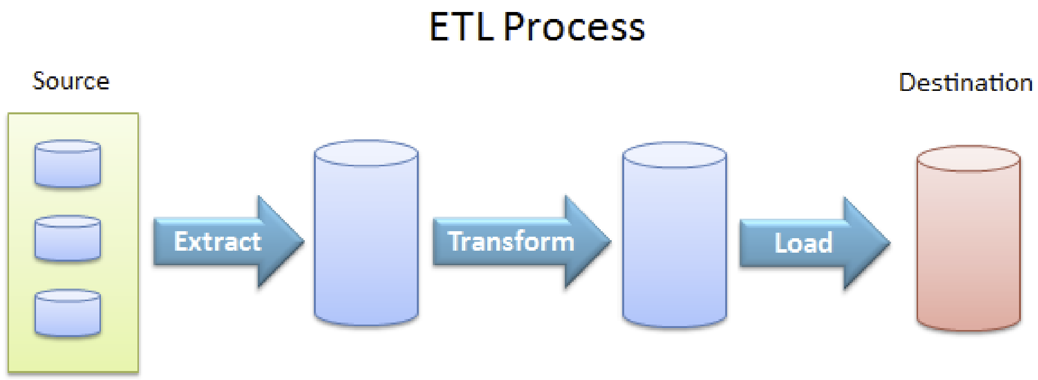


Figure A.2.1. Schema of the ETL (Extraction-Transfomration_Load) process.

The different steps that make up the ETL process are described in detail in the following subsections.

A.2.1.1 Step 1: Extraction of data

This step leads to the creation of SQL databases, one for each received database comprising two tables each: one with the **raw data** and the second one with the **metadata** concerning the data source and the details of the extraction process.

As we did not have access to raw data during data collection but flat file extractions from existing databases, received data responded more or less to our request depending on whether the consolidated data already existed or if the files were specifically extracted for the AMBER project (see sections 2.2 and 2.3). There are two main cases: one case where the data are available in the form of a GIS; and another case where the data are provided in one or more Excel files. The advantage with GIS data is tha this represents a well-formatted database with easy visualization of attributes. On the other hand, Excel does not represent the best solution for data exchange. Indeed, spreadsheets can contain extradata, which can lead for example to the loading of empty columns that do not match any attribute.

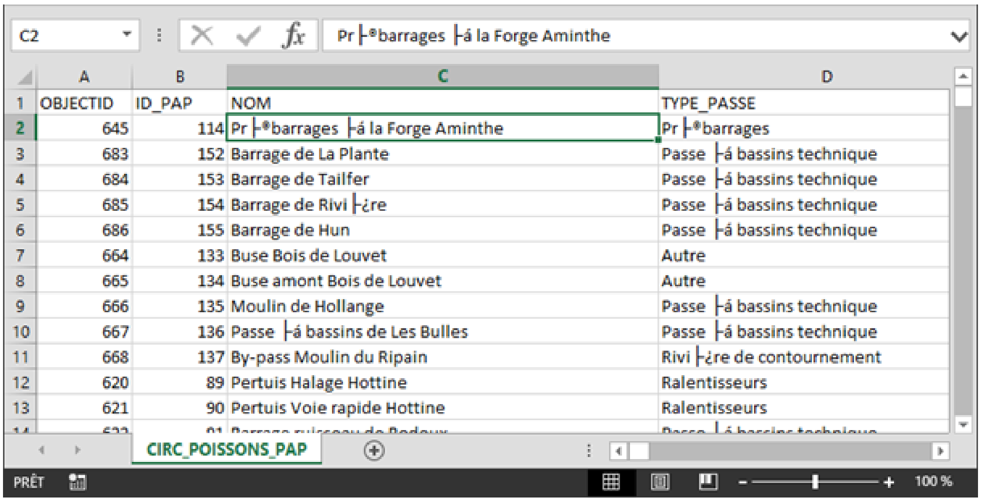
An attempt has been made to optimize the raw data processing via the ETL so that the overall process can be easily restarted when necessary. First of all, we have developed several **tools** for **extracting local data** for the specific types of file received (Excel, dBase, CSV). However, for certain databases it was difficult to propose easy rules to be implemented automatically and we had to develop **specific pre-processing**. For example, Wallonia has several databases, two of which have been used in this work: one for river barriers and another for fish passes. It was decided to merge these 2 databases before using the ETL. Another example is Wales, where the type of barriers is defined on 2 different fields (i.e. [FEATURE] and [TYPE]). Since there were no obvious rules in the distribution of informations between these two columns, rules have been developed to create a new unique field (i.e. [BarrierType]):

[BarrierType] = [FEATURE] + space + [TYPE]

with:

- If [TYPE] ends with “?” Then [TYPE] = “?”
- If [TYPE] contains “UNKNOWN” then [TYPE] = empty string

Working with data from several countries and several languages also needs to take into account the local alphabets and checking their native encoding. **Text encoding** is the process of transforming bytes of data into readable characters by using language-specific characters set. There are many encoding formats, some requiring a different character set for each language, such as MS-DOS; others like UTF-8, which is based on the Unicode character set and uses one byte (8 bits) to encode each character, include most characters of all languages in a single character set. This information was not provided with the data and it was necessary in some cases to find a correct encoding. For example, for Wallonia the default encoding proposed by Excel was incorrect (ANSI; Figure A.2.2). It was therefore necessary to manually search for the right encoding in order to correctly parameterize the extraction of the data (UTF-8).



	A	B	C	D
1	OBJECTID	ID_PAP	NOM	TYPE_PASSE
2	645	114	Pr ├®barrages ├á la Forge Aminthe	Pr ├®barrages
3	683	152	Barrage de La Plante	Passe ├á bassins technique
4	684	153	Barrage de Tailfer	Passe ├á bassins technique
5	685	154	Barrage de Rivi ├¿re	Passe ├á bassins technique
6	686	155	Barrage de Hun	Passe ├á bassins technique
7	664	133	Buse Bois de Louvet	Autre
8	665	134	Buse amont Bois de Louvet	Autre
9	666	135	Moulin de Hollange	Passe ├á bassins technique
10	667	136	Passe ├á bassins de Les Bulles	Passe ├á bassins technique
11	668	137	By-pass Moulin du Ripain	Rivi ├¿re de contournement
12	620	89	Pertuis Halage Hottine	Ralentisseurs
13	621	90	Pertuis Voie rapide Hottine	Ralentisseurs

Figure A.2.2. Example of encoding problems with the database from Wallonia (in French; CIRC_POISSONS_PAP = database name). The columns NOM (i.e. barrier name) and TYPE_PASSE (i.e. fish pass type) include some accents that are not recognised by the default encoding language proposed in excel (i.e. AINSI).

The result of the encoding change (ANSI -> UTF-8) can be seen in Figure A.2.3.

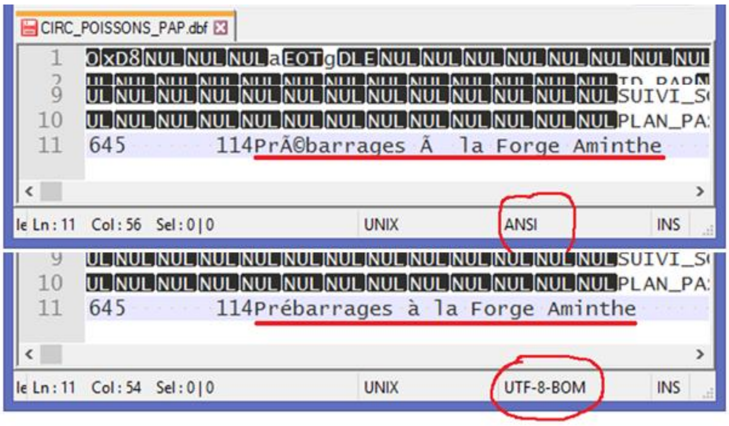


Figure A.2.3. Example of encoding transformation for the database from Wallonia (in French) from ANSI to UTF-8 encoding. It can be seen that the UTF-8 is able to encode the accents used in the French language.

The data is finally recorded with a UTF-16 encoding, native for SQLServer, accounting for all European languages.

A.2.1.2 Step 2: Transformation of data

In each database, a new table was created in the ATLAS format to store the transformed data. The details of the operations performed during the transformation are stored in additional tables.
The tasks of data transformation may differ according to the source database but mainly include:

Task 1: analyzing the relational structure of the source databases;

Task 2: geographical coordinates processing;

Task 3: creating typology tables to manage barrier types;

Task 4: creating a subset of the imported data to retain only the useful data to populate the atlas.

Task 1 leads to the **selection** of data to be used, that corresponds to (i) **mapping attributes**, in order to select the fields in the local database that will be used for the ATLAS; (ii) **data filtering** in order to select the records in the local datasets that will be used for the ATLAS.

The (i) **mapping** consists first of all in determining the list of attributes that are relevant to the ATLAS database, and secondly it is necessary to determine in which fields of the ATLAS database this information will be stored. Indeed, received files contain all or only some attributes corresponding to those relevant for the ATLAS (i.e. the key parameters of Table 2.2.1), but they may also contain supernumerary attributes that we planned to store and that can be used later within the project (see section 2.3 for details on received databases). This step within AMBER has been supported by the answers to the questionnaire on complementary information asked during the phase of database collection (see section 2.2.). For example, the response to the questionnaire described in section 2.2 for the French data contains the mapping details for the ROE database. The correspondence between the source attributes and the key attributes of the ATLAS is reported below (see section 2.3.2 for further details):

- Database name: CdObstEcoul
- URL: http://www.sandre.eaufrance.fr/atlas/...
- Country: “FRANCE”
- Longitude - Latitude: CoordXPointCarOuvrage – CoordYPointCarOuvrage
- River: NomEntiteHydrographique
- Basin: NomCircAdminBassin
- Height: HautChutEtObstEcoul – HautMaxTer
- Barrier type: CdTypeOuvrage (type code) / LbTypeOuvrage (type name)
- Fish pass: CdTypeDispFranchPiscicole (type code) / LbTypeDispFranchPiscicole (type name).

The (ii) **filtering** is necessary in order to select only the part of the supplied records corresponding to the ATLAS key variables. There are two cases:

- data have not been validated by the local administrators which means that these data should not be used routinely; for example, in the French database only the records having the value "Validé" for the field [StObstEcou] (i.e. barrier status) were selected;

- the barriers clearly identified as natural were not selected; for example, in the Swedish database the records with the value "YES" for the field [NaturligtHinder] (i.e. natural barriers) were not selected.

Task 2 allows for **transform geographical coordinates** into a common system. Indeed, each country use one or more geographic coordinate systems to deal with the complexity of positioning and measuring. For the ATLAS purpose, it has been chosen to convert all local coordinates to the World Geodetic System (WGS84). This system is similar to INSPIRE CRS (ETRS89-XYZ) and has the advantage of being the default in all handheld GPS.
In order to perform the tranformation it is important to know the original geodetic datum used in the local files (i.e. EPSG system). While some data are already provided in WGS84, for others the datum has been provided, for some finally nothing is indicated and the refence has to be found manually. The geodetic datum can be derived from the characteristics of the source system (for example France uses RGF93 / Lambert-93), that are available for different countries on the web (e.g. “Epsg.io” is an easy-to-use geographical web service for this purpose; http://epsg.io).

Once the geodetic system for each database is known and the EPSG value provided, the transformation can be automated within the ETL process. For this purpose, we developed a common tool for AMBER users. This tool is based on the PROJ4 opensource library (http://proj4.org).

Task 3 concerns the management of **typologies** (e.g. barrier types). As we have not access to the raw data, we have to recover the relational structure of the original databases. Hereafter in the section two specific terms are used to refer to barrier types: typologies and dictionaries, both listing types describing the same objects. The **typologies** are multiple (one per area/database) and correspond to the types defined at national or regional level, whereas the **dictionaries** are the synthetic translations of these local typologies at the pan-European level and will be defined within the AMBER framework (see Table 2.2.1 and Annex B). Currently the ETL does not deal in detail with the dictionaries that will be fed later, because an official AMBER list of barrier types has to be defined (see section 4). It is also worth noting that each database can include 2 variables dealing with typologies: one for barriers and one for fish passes when available (see section 2.1). Task 3 also deals with fish pass types.

Hence, once Tasks 1 and 2 are performed and local databases are created and populated, each local typology (e.g. types of barriers) must be analyzed to be translated into the ATLAS dictionaries. For example, Table A.2.1 presents the detailed typologies of barriers in Switzerland and England. It appears that the typologies used by these two countries are different and that the definition of dictionaries will not simply be a question of translation.

Table A.2.1. Example of the typologies of barriers for one of the available Swiss databases and the English database (AMBER_SWITZERLAND_Structures_dams and AMBER_ENGLAND, respectively)

DBName	LabelSource
AMBER_SWITZERLAND_Structures_dams	Bed-load dam
AMBER_SWITZERLAND_Structures_dams	Weir
AMBER_SWITZERLAND_Structures_dams	Unknown
AMBER_SWITZERLAND_Structures_dams	Tyrolean weir
AMBER_SWITZERLAND_Structures_dams	Sluice
AMBER_SWITZERLAND_Structures_dams	Dam (reservoir)
AMBER_SWITZERLAND_Structures_dams	Spillway
AMBER_ENGLAND	BARRAGE
AMBER_ENGLAND	CULVERT
AMBER_ENGLAND	DAM
AMBER_ENGLAND	FORD
AMBER_ENGLAND	LOCK
AMBER_ENGLAND	MILL
AMBER_ENGLAND	SLUICE
AMBER_ENGLAND	UNKNOWN
AMBER_ENGLAND	WEIR

Recovering typologies consists of finding recurring words describing objects (i.e. barriers and fish passes) and creating tables to store these lists that contain the names of the types and unique keys that identifies them. Finally, the objective is to replace in the ATLAS dataset the names of the types found in the local databases by their keys which refer to the names in the typology tables.

For the French database (i.e. ROE database) we had to deal with two typologies: types of barriers and types of fish passes. For barrier type, both the key [CdTypeOuvrage] and the label [LbTypeOuvrage] were available to classify the type of barrier. As shown in Figure A.2.4, the objective was to keep the [CdTypeOuvrage] attribute in the main table (tb_local_Atlas) and to outsource the [LbTypeOuvrage] attribute on the typology table (tb_BarrierType), The relationship between the 2 tables being done by the primary key of the tb_ BarrierType table (i.e. GUID) and the foreign key of the tb_local_Atlas table (i.e. GUID_BarrierTypeCode). The blue arrows show the implementation of the typologies while the green dotted arrows show an example of the mapping process.

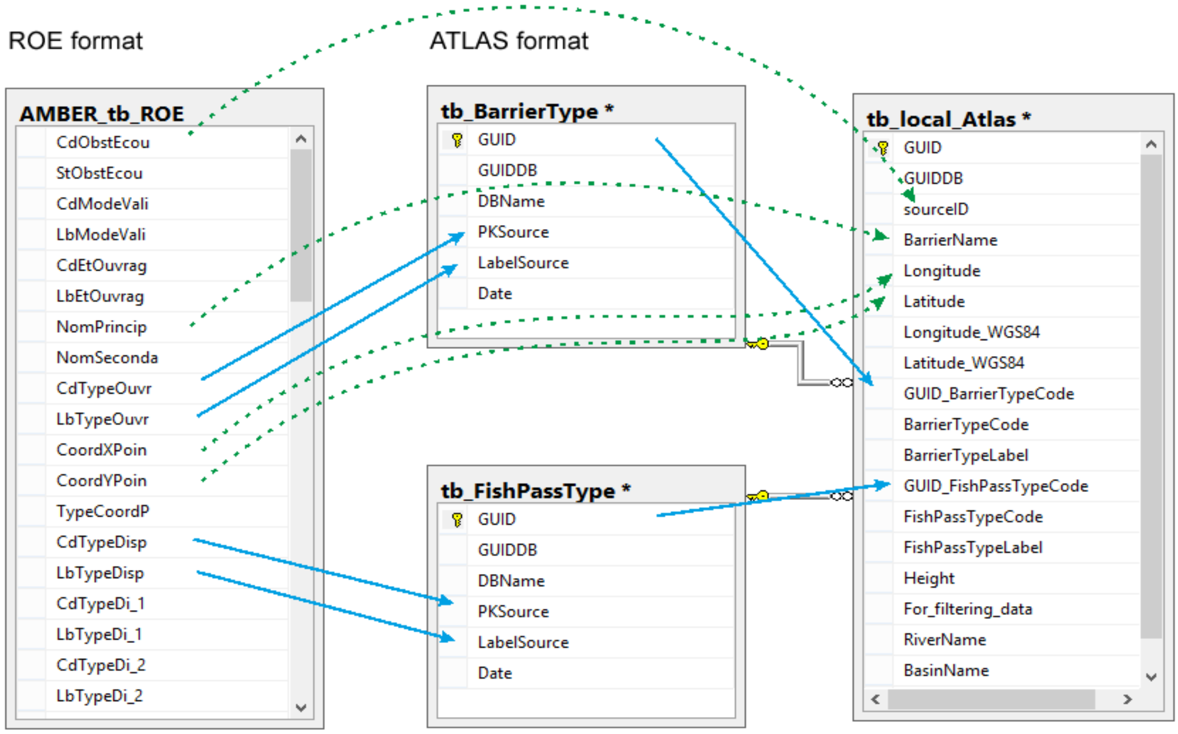


Figure A.2.4. Relationships between the source table (AMBER_tb_ROE; rows correspond to different column entries included within the source database), typologies tables (tb_BarrierType and tb_FishPassType) from the French database and the main table to be loaded within the ATLAS (tb_local_Atlas). Blue arrows show the implementation of the typologies while the green dotted arrows show the mapping task (including examples of corresponding translations).

The next step concerns the translation of typologies through dictionaries. Given that dictionaries are not yet finalized within AMBER and they are likely to evolve during the project, it is not possible to define definitive relationship between source types and those of the ATLAS. Without this information, it is necessary to envisage cardinalities (i.e. the precise and exact relationship between one data table to another; it can be "one-to-one" (1:1), "one-to-many" (1:N) or "many-to-many" (M:N)) making possible to manage all possible future relations between the source typologies and those of the ATLAS (Figure A.2.5).

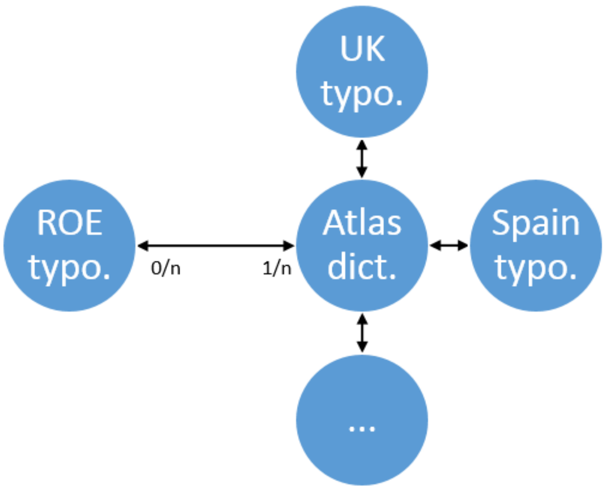


Figure A.2.5. ***Many-to-many relationship between source tables and Atlas table***

For example, looking at the French/English dictionary, we can find a 1:1 cardinality for translation:

barrage ⇔ dam

But it may happen that 3 categories of dams exist for the barrier typology in a given database (e.g. gravity dam, arch dam and buttress dam) whereas in the ATLAS dictionary only one type of dam exists (i.e. dam). In this case, the cardinality is more complex namely a many-to-many relationship (i.e. a cardinality M:N).

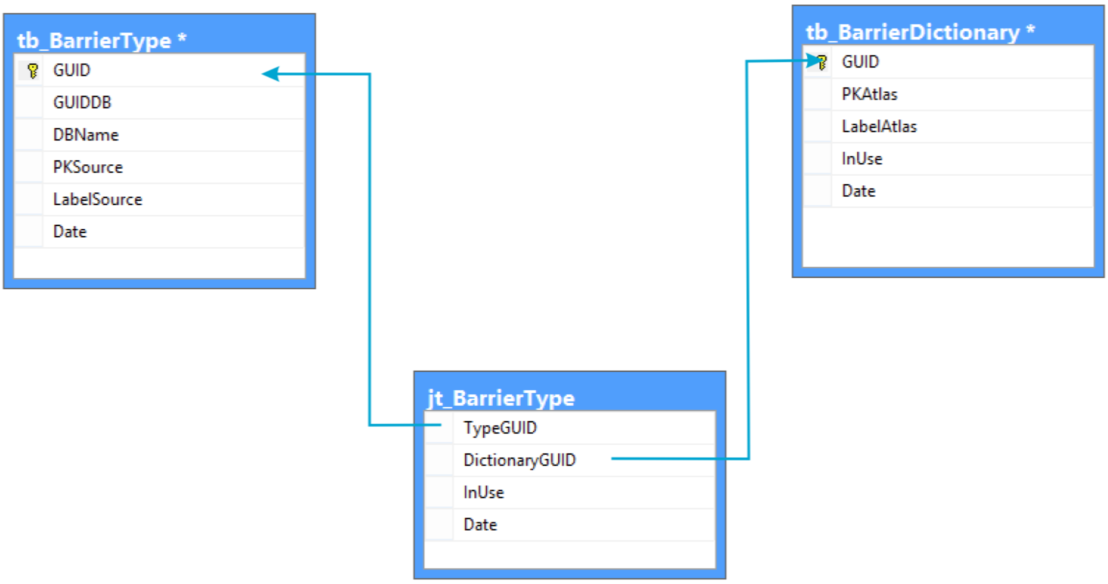


Figure A.2.6. Example of the relationship between typologies (tb_BarrierType) and dictionaries (tb_BarrierDictionary) through the use of a junction table (jt_BarrierType). GUID (globally unique identifier) is a primary key that allows to identify database entries uniquelly (see below for further detail).

To solve the problem of many-to-many relationships within a relational database, it is necessary to make use of junction tables (i.e. tables that can contain references to columns from the same or different tables within the same database, named foreing keys; Figure A.2.6). These will allow to modify the typologies according to the needs of the project.

Figure A.2.7 shows an example of translation for the ROE database. The typology and the dictionary tables (tb_BarrierType and tb_BarrierDictionary, respectively) are independent and all the work of relation and translation is done by the junction table (jt_BarrierType), which can be modified to take account of future imports and typologies.

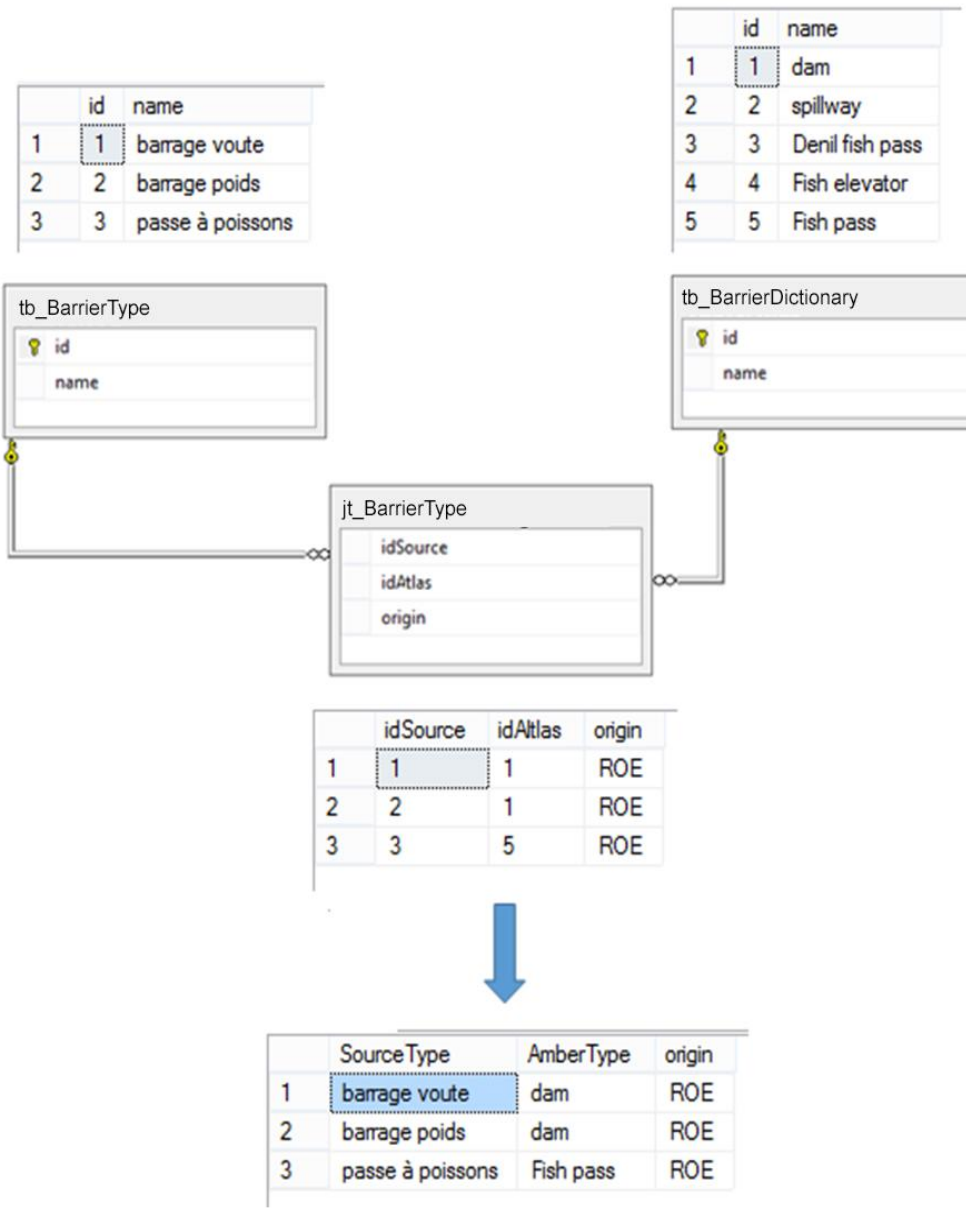


Figure A.2.7. Example of translating a typology of the French database (tb_BarrierType) using an Atlas dictionary (tb_BarrierDictionary) and a junction table (jt_BarrierType). For demonstration reasons, it has been used a key of type "integer" to identify barriers, namely "id". Examples of barrier types within the French database: barrage voute = arch dam ; barrage poids = gravity dam; passe à poisson = fish pass.

In the example of Figure A.2.7, it appears that the classic use of "integer" keys (i.e. "id") works perfectly when consolidating a single database, but this is not the case when multiple consolidation must be performed. In principle, any record (row) in a table is identified by a unique identifier (i.e. PK, primary key). This identifier allows joins to be made between different tables (PK / FK, where FK means foreign key). Very often, the value of the primary key field is automatically created as an auto-incremented integer (see Figure A.2.8). However, when dealing with several data sources, we face the problem of keys duplication. In the example of Figure A.2.8, if we merge Table1 and Table2, the values "1" and "2" are now doubled in the consolidated list. So, "id1" is no longer a primary key (which by definition must be unique for the same table) since it refers to 2 records with different names "aaaaa" and "ccccc". The same situation is found with "id2" and so on (Figure A.2.8).

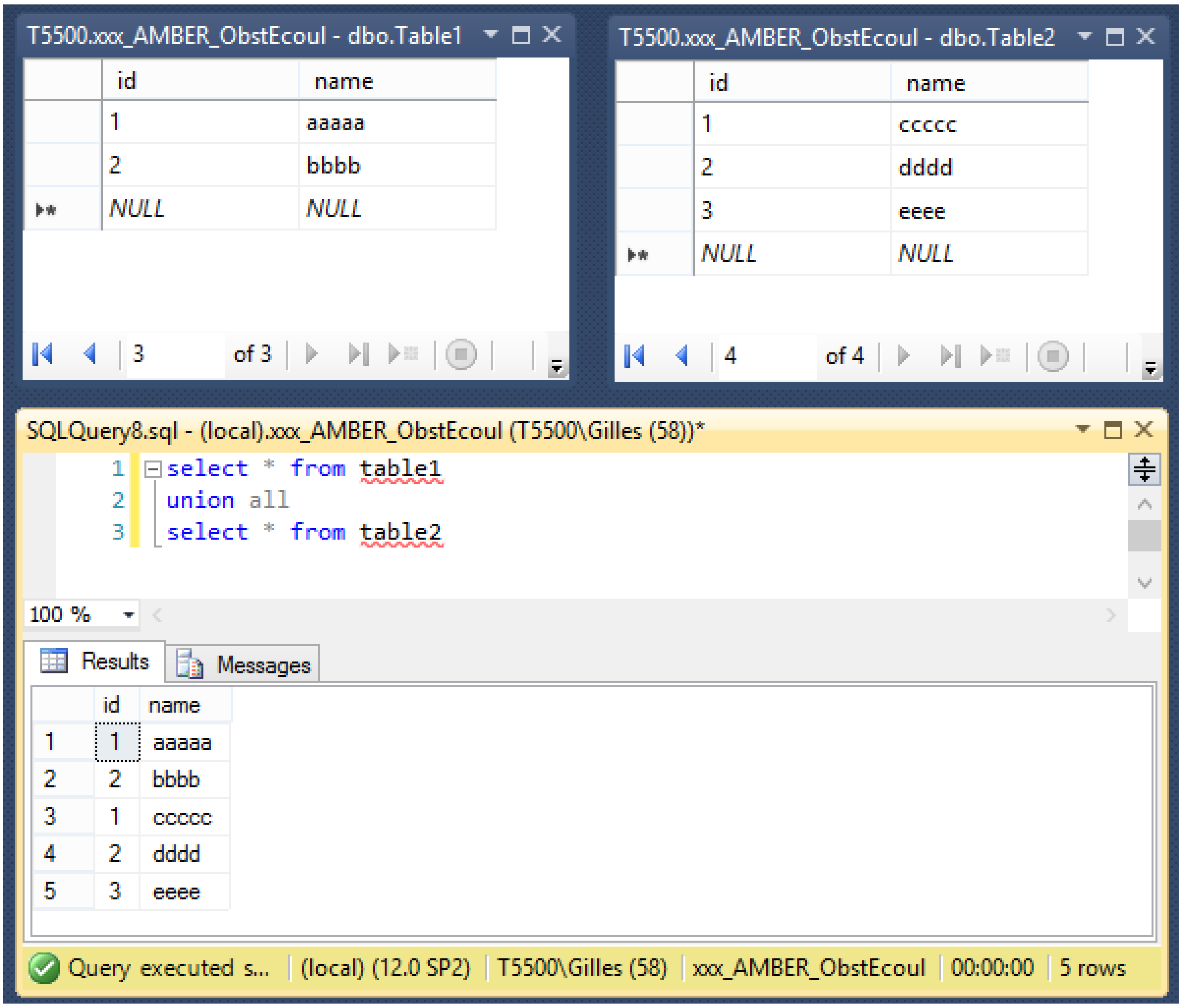


Figure A.2.8. Example of duplication of primary keys during a merge.

This problem may propagate at each consolidation. For the purposes of the ATLAS it has been necessary to modify the type of the primary keys and use GUIDs (globally unique identifier). GUIDs are large numbers (128-bit value) that are nearly guaranteed to be unique. GUIDs are the Microsoft implementation of the universally unique identifier (UUID). The same example of Figure A.2.8 is reported using GUIDs keys in Figure A.2.9. It displays that GUID guarantees the uniqueness and identification of all records and allows the merge of databases without duplicate problems.

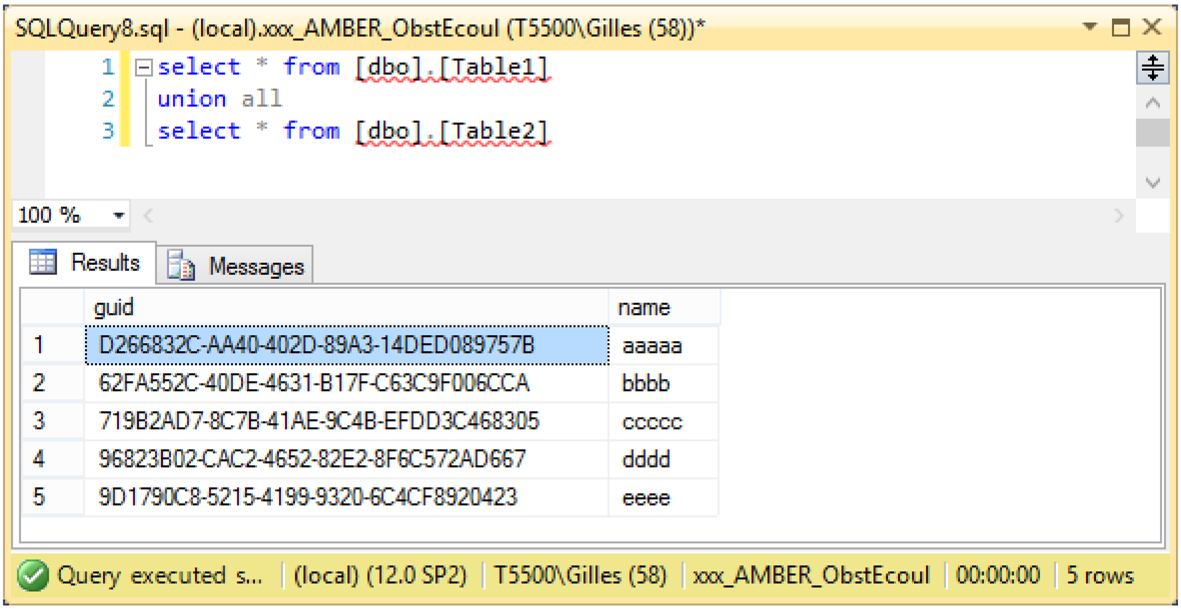


Figure A.2.9. Respect of primary keys with GUIDs during the merge.

Moreover, for each data extraction each new database is authenticated by a GUID, which will also allow to manage future imports for consolidation.

A.2.1.3 Step 3: Loading data

The results of previous steps allow to store data in several datasets and tables as follows:

1. the tables with raw data (eg. AMBER_tb_ROE)	n	local databases
2. the transformed data tables (tb_local_Atlas)	n	
3. the typology tables (tb_BarrierType, tb_FishPassType)	2 x n	
4. the merged typology tables (tb_BarrierType, tb_FishPassType)	2	ATLAS database
5. the ATLAS dictionaries (tb_BarrierDictionary, tb_FishPassDictionary)	2	
6. the join tables (jt_BarrierType, jt_FishPassType)	2	
7. the ATLAS table (tb_merged_Atlas)	1	

From an operational point of view the ATLAS database contains seven tables. In order to view the consolidated and translated data and get the ATLAS result-set, we have to make a query on these 7 tables (Figure A.2.10). For example, for the analyses of section 2.4 we made a query to extract only the main key variables of Table 2.2.1 (see also Table A1 Annex D1.1 Part B).

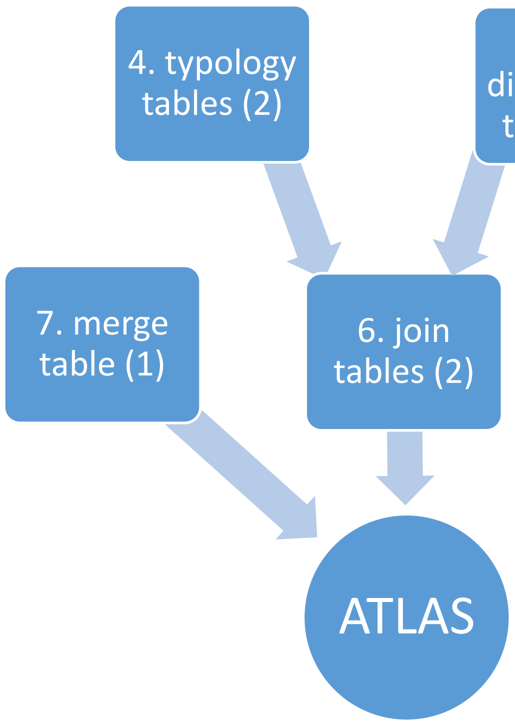


Figure A.2.10. The ATLAS result-set obtained by merging the last 4 groups of tables listed above (4 to 7).

Overall, this means that at each data change in any of the seven tables, the ATLAS resultset changes accordingly. Vice versa, the data in the "ATLAS" cannot be directly changed. Hence the "ATLAS" is not a physical table but a dynamic and read only result-set.

Step 3 of the ETL is performed using scripts written in Transact-SQL.

A.2.2 Summary and conclusions of the ETL process and ATLAS structure

After Steps 1 and 2 of the ETL process, each local dataset leads to the creation of a database called [ATLAS_xxxxxx] which contains entries, transformed data as well as metadata. Each of these databases is identified by a name and a GUID which guarantees its uniqueness, and which also allows to manage future updates. Step 3 leads to the database "ATLAS_AMBER" with the 7 main tables and the metadata allowing for query analyses.

The Figure A.2.11 displays the flow of operations for creating and maintaining the ATLAS database using the ROE data processing example.

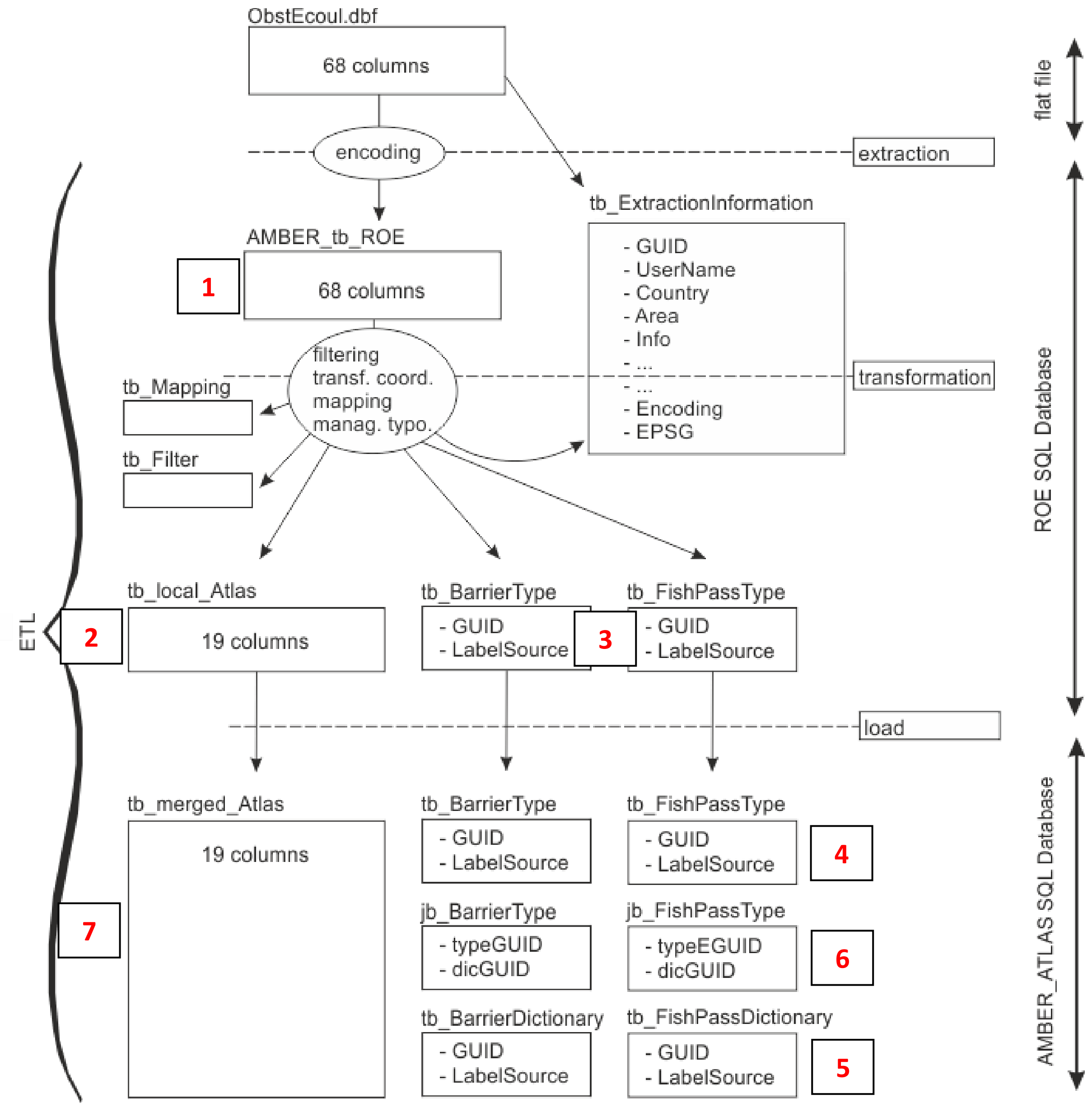


Figure A.2.11. Summary of the entire ETL process for the French database (ROE). The 7 groups of tables listed in section A.2.1.3 are also displayed.

ANNEX B: BARRIER TYPES

A list and brief description of types of river barriers included in the present report is provided.

Dam

A dam is a barrier that blocks or constrains the flow of water and raises the water level, forming a reservoir. Dams come in many shapes and sizes. Dams are often used to provide water supply and for generation of electricity. It causes a significant alteration of flow and sediment discharges and a complete interception of bedload.

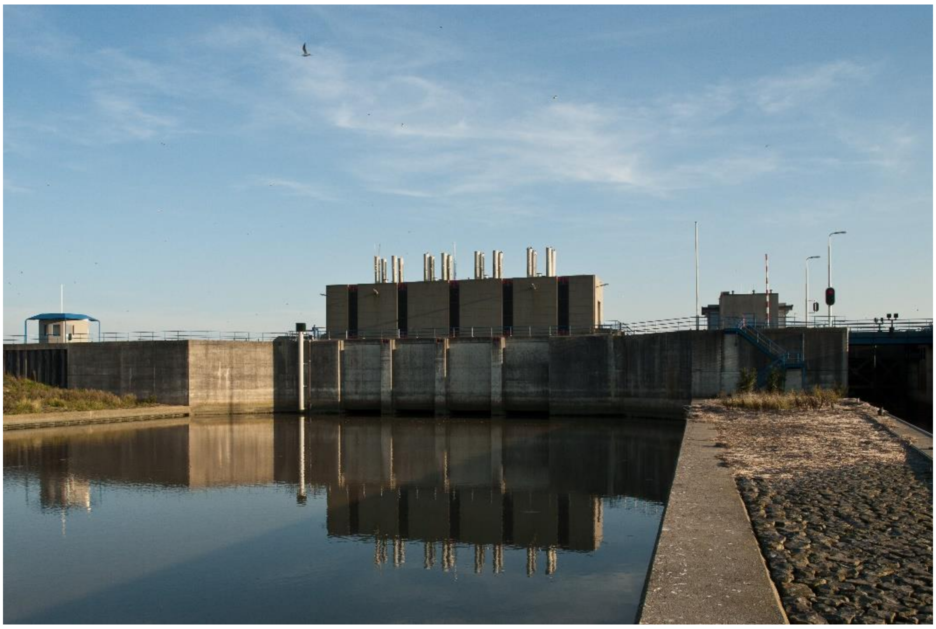
Dam (Dora Baltea river, Italy). Picture: S. Bizzi

Weir

A weir is a barrier aimed at regulating flow conditions and water levels or at intercepting sediment or at reducing the channel slope for stabilizing the channel bed of a river or stream. Water often flows freely over the top of a weir. Weirs come in many shapes and sizes (e.g. in mountain areas: retention and consolidation check dams; in lowland areas: consolidation or abstraction weirs) but often have a height of less than 5 meter.

Left: consolidation weir (Arno river, Italy). Right: retention check dam (Marecchia river, Italy). Pictures: S. Bizzi (left), B. Belletti (right)

Sluice
A Sluice is a movable barrier aimed at controlling water levels and flow rates in rivers and streams. By opening or closing the sluice, water levels and flow rates can be altered. Sluices come in many shapes and sizes. Sluices are also used in ship locks, to allow ships to navigate passed dams or other obstructions which create uneven levels of water.



Picture: J. Van Deelen

Ford
A Ford is a structure in a river or stream which creates a shallow place for crossing the river or stream by wading.

Ford (Orco river, Italy). Picture: M. Micotti

Culvert

A Culvert is a structure aimed at carrying a stream or river under an obstruction. Culverts are often embedded in soil and come in many shapes and sizes, varying from round and elliptical to box-shaped.

Picture is taken from Rinaldi et al., 2015 (http://www.reformrivers.eu/geomorphic-units-survey-and-classification-system-gus).

Ramp and bed sill

A Ramp or a bed sill is a structure aimed at stabilizing the channel bed and reducing erosion. Ramps and bed sills come in many forms. They can be underwater structures (i.e. not blocking the flow of water, only acting on river bed and channel slope) but often have a height of less than 1-2 meters.

Bed sill (Marecchia river, Italy). Picture: B. Belletti

ANNEX C: FIELD SHEET

River					
Date					
ID (progressive)					
Barrier type	Dam				
	Weir				
	Culvert				
	Ford				
	Sluice				
	Ramp-Bed sill				
	Unknown				
Height	<0.5 m				
	0.5 - 1 m				
	1 - 2 m				
	2 - 5 m				
	5 - 10 m				
	>10 m				
In-use?	Y				
	N				
	Don't know				
Full width	Y				
	N				
Location (notes)					
Notes / Description					
Picture(s)					