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A curated dataset on the distribution of West Palaearctic freshwater bivalves

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Freshwater bivalves (FWB) are attracting scientific and societal attention given their essential ecosystem services, ecological functions, and poor conservation status. Current knowledge of the spatial distribution of West Palearctic FWB is poor preventing the understanding of biogeography and conservation planning. One of the priorities of the pan-European networking project "CONFREMU - Conservation of freshwater mussels: a pan-European approach" funded by the European Union, was to fill the knowledge gap on the distribution of FWB in Europe and adjacent regions. Based on the efforts of this network of scientists, we provide the most complete, taxonomically, and geographically accurate distribution of FWB species for the entire West Palearctic. The dataset contains 270,287 geo-referenced records of 93 native and 8 non-native FWB from 1674 to 2023. The dataset compiles information from private records from 82 specialists and multiple sources (e.g., published articles, grey literature, biodiversity databases, and scientific collections). This dataset, available online, represents an important data source for future studies on the biodiversity, biogeography, and conservation of these important organisms.

Background & Summary

The West Palearctic is one of the most anthropogenically altered regions on Earth, and its freshwater habitats in particular have been drained, polluted and physically degraded by human activities over the past millennia[1,2]. As a result, freshwater species, especially those that are more sensitive to human disturbance, have dramatically declined or even disappeared from this region[3,4]. This is the case of freshwater bivalves, one of the most imperilled groups of animals on Earth[5]. Although the ecological importance of these animals is increasingly recognised, information on their distribution and population trends is highly fragmented, making effective conservation a challenge[6,7].

In the West Palearctic, there are only 93 species of native freshwater bivalves, compared to almost 10,000 recognized extant species of bivalves worldwide, of which approximately 86% are marine[8]. The remaining species inhabit freshwater and correspond mainly to two speciations in this environment: the freshwater mussels (also known as naiads) of the Unionida order with about 1,000 species, and the pea or fingernail bivalves of the Sphaeriida order, which includes roughly 250 species[7,8]. These groups account for almost 90% of all freshwater bivalve species worldwide. The few remaining species are found scattered across other bivalve groups[5]. In the West Palearctic, the native diversity of freshwater bivalves (see Supplementary Table 1 for the complete list) is mainly composed of the two major groups already mentioned: the freshwater mussels with 43 species and the fingernail/pea bivalves with 39 species. The remaining species include *Corbicula fluminalis* from the Cyrenidae family and 10 species of the family Dreissenidae (which generally attach to stones or any other hard surface using a byssus thread).

Eight non-native species also occur in the region. This includes: one East Palearctic Asian freshwater mussel (the Chinese pond mussel *Sinanodonta woodiana*); two Nearctic North American pea bivalves (the Long peaclam *Sphaerium transversum* and the Ridgebeak peaclam *Euglesa compressa*); three East Palearctic Asian cyrenid clams (*Corbicula fluminea*, *C. leana*, and *C. largillierti*); and finally, two species which are primarily found inhabiting brackish environments, although they can also be found in freshwater habitats (the Conrad's false mussel *Mytilopsis leucophaeata* and the gulf wedge clam *Rangia cuneata*). Except for *S. tranversum* and *E. compressa*,

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which do not appear to have spread widely[9], all other non-native species have traits that can result in competition with native species[10] and significant ecological and economic damage in the areas they invade[11]. This includes *C. fluminalis* and two of the dreissenid species, the zebra (*Dreissena polymorpha*) and the quagga (*D. bugensis*) mussels that, despite being native to the Ponto Caspian region, have now expanded extensively to other regions of the West Palearctic[12].

Conservation status and Distribution related issues

The conservation status of freshwater bivalve groups in the study area varies considerably. Freshwater mussels (Unionida) are highly imperilled, with 77.3% of the species assessed as Threatened or Near Threatened[13], while only 8.3% of the pea bivalves (Sphaeriida) fall into these categories[13]. Precise and dependable conservation status assessments demand accurate distribution and trend analyses, given that almost all freshwater bivalve assessments rely on distribution-related traits. Criterion C of the IUCN Red List, which estimates population size and trends using the number of individuals, is notably arduous to apply in conservation assessments of elusive underwater invertebrates like freshwater bivalves. Therefore, all conservation assessments of freshwater bivalves use criteria A (population size reduction) and B (limited distribution range) from the IUCN Red List. Moreover, most (81%) assessments using Criterion A generally estimate population declines based on distribution parameters such as Extent of Occurrence (EOO) and Area of Occupancy (AOO)[13].

Recent studies in systematic conservation planning reveal that extensive protected area networks, mainly intended for conserving terrestrial biodiversity, such as the Natura 2000 network in Europe, do not provide sufficient protection for freshwater biodiversity[14]. It is therefore essential to improve the representation of freshwater biodiversity in these networks and enhance their capacity to address threats and specific ecological needs[15]. Accurate and comprehensive distributions of freshwater species are crucial in identifying important conservation areas, as these exercises rely heavily on species distributions and patterns of species aggregation and composition.

Several sources containing documented distributions of freshwater bivalves are readily available, such as GBIF (https://www.gbif.org/), particularly for the larger and more conspicuous freshwater mussels. However, species identifications in these databases are based on shell morphology since the majority of records are derived from shell collections[16]. Identification of freshwater bivalves using shell morphology demands significant expertise, particularly of the minute pea bivalves with some species exhibiting noteworthy shell similarity[17]. In addition, various genera display cryptic diversity where morphologically indistinguishable species are distinct only at the molecular level[18,19]. Conversely, certain species that were previously thought to be separate exhibit introgression and were subsequently considered as a single species[20]. Therefore, the accurate identification of freshwater bivalves presents a considerable challenge, resulting in distribution databases of these animals that are highly unreliable and biased due to frequent misidentifications at the species level. Our current knowledge of the occurrence and spatial distribution of freshwater bivalve species in the West Palearctic is far from complete. New species have recently been described (e.g. in Sphaeriida: *Euglesa interstitialis*[21]; *Euglesa moroccana* and *Odhneripisidium caucasus*[17]; and in Unionida: *Anodonta seddonae* and *Leguminaia anatolica*[19]) and others may yet be undescribed in the less explored areas, such as most of the Caucasus, the Middle East, and parts of North Africa (Fig. 1). In addition, the dataset compiled here highlights major gaps in knowledge of the distribution of vast areas that are still largely unrepresented.

This dataset was created by collecting data from a variety of sources such as published articles, grey literature, field expedition records, regional and national administration report, and online databases dedicated to biodiversity and scientific collections maintained by museums, research institutions and universities. We also incorporated information collected during field expeditions (short-term scientific missions) conducted as part of the CONFREMU project. The project sought to gather the latest and most comprehensive data on the distribution of freshwater bivalve species across Europe and neighbouring countries, as well as to initiate scientific collection expeditions in under-studied regions to address gaps in knowledge.

This dataset includes 270,287 geo-referenced occurrence records covering almost five centuries (1674–2023) and contains information on 101 valid freshwater bivalve species occurring in the West Palearctic region (Fig. 1). To our knowledge, this is the first endeavour to gather distribution records of the complete freshwater bivalve fauna in the West Palearctic or even for Europe alone.

This dataset of Freshwater Bivalves distribution has the potential to function as an invaluable and enduring resource for research into ecological and conservation issues, as well as to draw attention to gaps in taxonomy and sampling.

Methods

Information sources. This dataset is the result of a collaborative effort involving 82 researchers from 29 countries, carried out under the framework of the COST (European Cooperation in Science and Technology) Action CA18239 – *Conservation of Freshwater Mussels: A Pan-European Approach* (CONFREMU), funded by the European Union. To initiate data compilation, a standardized datasheet template (see Data Records) was distributed to all contributors, who filled it with information based on their own field observations and/or bibliographic sources. These entries were then submitted to the lead author for individual curation, including the correction of errors and taxonomic standardisation using the most up-to-date nomenclature.

Data providers were selected based on their expertise in freshwater bivalves, and most contributed data at the national level. Given the wide geographic scope and depth of regional knowledge, the compilation drew from a highly diverse array of sources. To further enhance the dataset, a comprehensive literature search was performed using Scopus and ISI Web of Knowledge, incorporating both scientific and common names of all target species.

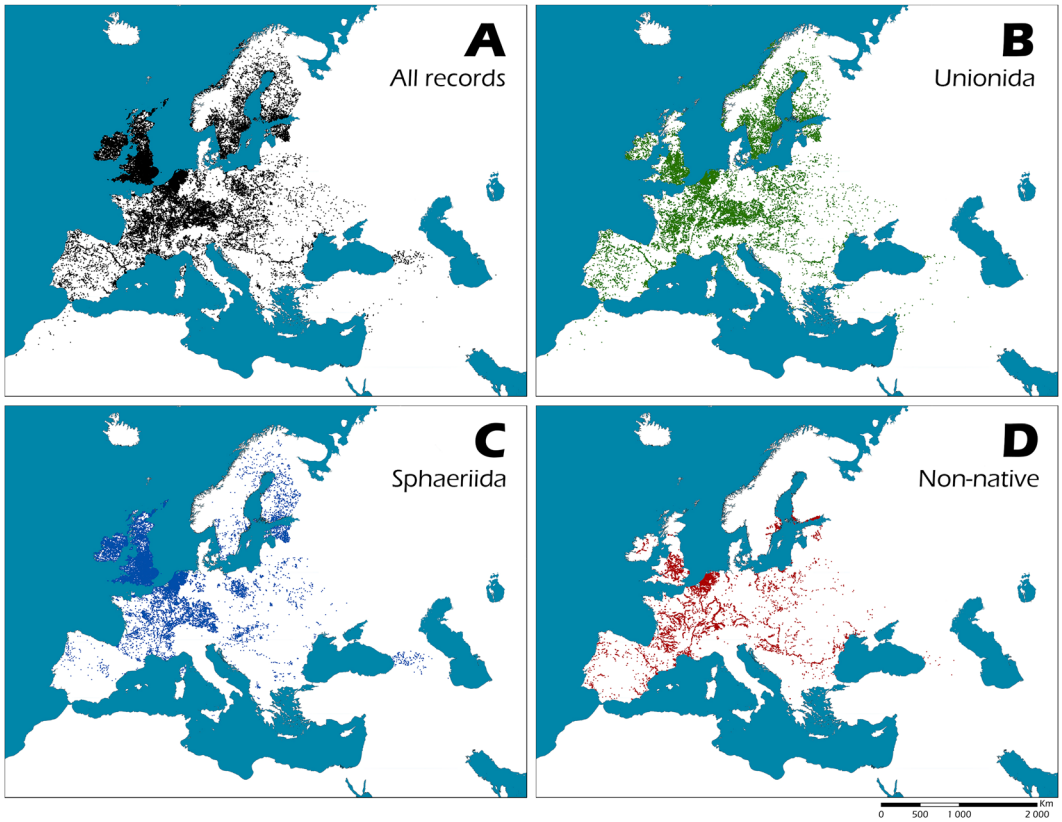

Fig. 1 Distribution maps of: (**A**) all records, (**B**) all freshwater mussels (Unionida), (**C**) all fingernail/pea bivalves (Sphaeriida), and (**D**) all non-native species from the dataset.

SOURCE	RECORDS	Country
Inventaire national du patrimoine naturel (INPN).	56,810	France
THIS STUDY	**44,671**	**Global**
GBIF - the Global Biodiversity Information Facility	37,465	Global
Limnodata Neerlandica	28,756	The Netherlands
The Netherlands Water Quality Survey	7,630	The Netherlands
Finnish Biodiversity Information Facility	9,973	Finland
Service public de Wallonie, Dir. Nature et de l'eau	7,720	Belgium
Biodiversity Databank Haus der Natur, Salzburg	6,363	Austria
All Ireland Molluscan Database.	5,679	Ireland
The Netherlands Nationale Databank Flora en Fauna	5,585	The Netherlands
Bavarian Environment Agency	5189	Germany
Conchological Society of Great Britain & Ireland.	4,599	United Kingdom & Ireland
Museums of Germany	4,301	Germany
Monitoring Waterstaatkundige Toestand des Lands.	3,934	The Netherlands
Nature Conservation Agency of the Czech Republic	3,360	Czechia
RBINS (Royal Belgian Institute of Natural Sciences).	2,625	Belgium
Hungarian Natural History Museum	2,166	Hungary
Flemish Environment Agency (VMM).	1,466	Belgium

Table 1. Sources with the highest contribution of records (>1,000) to the database, with full name, number of records, and country.

Field data collection by the co-authors employed three complementary methods, wading, snorkelling, and scuba-diving, allowing for thorough investigation across various aquatic habitats and substrate types. To ensure accuracy, only live specimens were recorded; observations of empty shells or fragments were excluded, as these could represent individuals no longer present or transported from other locations.

COUNTRY	AREA (SQ.KM)	RECORDS	SP. RICHNESS
France	548,780	55331	44
Netherlands	34,968	42951	35
United Kingdom	244,575	34090	33
Sweden	449,206	32207	30
Germany	357,242	21307	41
Belgium	30,671	10023	36
Finland	335,647	10048	31
Poland	311,947	8075	35
Ireland	69,809	7059	22
Spain	505,752	6508	25
Austria	83,964	6496	33
Norway	324,286	3545	15
Czechia	78,888	2935	21
Estonia	45,438	2677	11
Switzerland	41,262	2270	30
Hungary	93,119	1827	26
Slovakia	49,029	1262	19
Ukraine	600,353	989	25
Italy	301,631	943	13
Portugal	91,978	863	12
Luxembourg	2,621	592	24
Croatia	56,377	586	26
Bulgaria	111,300	554	31
Romania	237,980	456	16
Lithuania	64,945	328	29
Belarus	207,605	318	14
Serbia	88,478	301	17
Georgia	69,798	246	13
Greece	132,559	169	23
Slovenia	20,683	157	16
Türkiye	781,152	124	17
North Macedonia	25,424	98	14
Morocco	406,318	54	5
Albania	28,486	46	12
Latvia	64,563	19	4
Moldova	34,060	19	7
Tunisia	155,177	18	4
Montenegro	13,780	16	5
Denmark	44,441	15	5
Armenia	29,688	11	4
Azerbaijan	86,333	11	3
Syria	185,757	11	4
Bosnia and Herzegovina	50,993	8	5
Iran	1,621,476	3	2
Iraq	437,114	3	2
Cyprus	9,013	2	1
Lebanon	10,133	2	2
Israel	21,981	1	1

Table 2. Summary of records and species richness per country, ordered by decreasing number of records.

All co-authors brought extensive taxonomic and ecological expertise, contributing not only original data from their own collections and fieldwork but also facilitating the identification of additional data sources through their professional networks. Ultimately, information from a wide range of origins was consolidated and harmonised into a single, high-quality dataset.

This combined data incorporates six types of source data:

1. Gathered or compiled by the co-authors (e.g. from field expeditions, monitoring)
2. Literature (scientific articles, books, grey literature)

FIELD	DESCRIPTION
UNIQID	Database unique identifier
SPECIES	Species name
FAMILY	Family name of the species
DAY	Day of the record
MONTH	Month of the record
YEAR	Year of the record
LATITUDE	Latitude in WGS84 decimals
LONGITUDE	Longitude in WGS84 decimals
TYPE OF RECORD	Type of record collected (observation, reference and museum voucher)
RECORDED BY	Person who recorded the observation
COMPILED BY	Name of compiler of the information
REFERENCE	Complete literature reference

Table 3. Fields and full description of the database records.

3. Research and conservation projects
4. Online biodiversity databases
5. Museum, research institutions, and university collections
6. National & regional databases on nature conservation
7. Data from environmental agencies

The majority of the data were extracted from the most widely used and frequently updated biodiversity databases (see details in Table 1). These repositories make biological data available under a Creative Commons licence in which the user agrees to acknowledge the source of the data. A total of 44,671 records were derived from field data collected by the co-authors or by them from national colleagues. A total of 1,629 documents (e.g. scientific articles, books, grey literature) containing over 25,000 records on the distribution of freshwater bivalve species were identified by the 82 co-authors. Data (3,540 records) from museum collections were obtained directly from museum curators or online museum databases. Any redundant records with other data sources were eliminated. There is an imbalance in the geographical distribution of records by country, with countries in central and north-western Europe providing a higher number of records (Table 2). The opposite is true for most countries in Asia and Africa, where the number of records is very low (Table 2), highlighting the need for investment in surveys in these countries. It also highlights the failure of the network to attract researchers with data from European countries such as Denmark and Bosnia-and-Herzegovina. For some countries, the limited capacity of the researchers involved meant that it was not possible to import existing records, such as the extensive Sphaeriida records from Sweden and Norway.

Data Records

The dataset is available at figshare[22]. It consists of a spreadsheet with 270,287 records, each represented as a row. The fields on each record, with self-explanatory headers, contain the updated species name, the date when it was collected, the provider and compiler of the information, and then the source of the information, which may be a scientific paper, grey literature, museum or database record, or the own field records of the provider (Table 3). A more detailed data description and access rules for the data of some countries can be found in the supplementary data statement.

Technical Validation

Each record in the dataset comprises 12 fields and was only included in the final compilation if it contained essential information on the species name, year of collection, collector or observer, and geographical location (Table 3). The scientific names of all reported species were carefully verified to correct typographical errors or misspellings. Taxonomic information was then standardized and updated using Molluscabase[8] to ensure consistency with current nomenclature. Species within the Unio crassus complex were reassigned according their biogeographic context following. To avoid duplication, all records were cross-checked for multiple entries submitted by different data providers and consolidated into single entries where necessary[23].

All records in the complete dataset were georeferenced, with an accompanying measure of spatial accuracy. Although the original data were collected with precise geographical coordinates, the accuracy was generalized to a 10×10 km grid to protect sensitive species, particularly those of conservation concern or with legal protection, such as *Margaritifera margaritifera*, to mitigate risks like illegal pearl fishing. The full dataset is available via the Figshare repository[22] and online at https://e-mussels.eu.

Usage Notes

Species occurrences can be downloaded at[22] with a grid resolution of $10 \times 10\,km^2$ and be viewed online (https://e-mussels.eu) with different grid sizes from $10 \times 10\,km^2$ to $100 \times 100\,km^2$. The dataset comprises the geographical coordinates for each record, its information source, and the species name, according to the Molluscabase[8] taxonomy.

Code availability

No custom code has been used in the manuscript.

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Author contributions

T.Z. and M.L.L. created the first dataset version. R.S. idealized the manuscript. M.L.L. compiled the data, checked, and validated the taxonomy and wrote the first version of the manuscript. All authors contributed substantially by providing data, checking the information on distribution and taxonomy of the species and by reviewing the manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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