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Revising the freshwater section of the EUNIS habitats classification - A scoping paper updated July 2016

Gertie Arts and Joop Schaminée

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Authors' affiliation:

Gertie Arts, Wageningen Environmental Research (NL)
Joop Schaminée, Wageningen Environmental Research (NL)

EEA project manager:

Mette Palitzsch Lund, European Environment Agency (DK)
Annemarie Bastrup-Birk, European Environment Agency (DK)

ETC/BD production support:

Muriel Vincent, Muséum national d'Histoire naturelle (FR)

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European Topic Centre on Biological Diversity
c/o Muséum national d'Histoire naturelle
57 rue Cuvier
75231 Paris cedex, France
Phone: + 33 1 40 79 38 70
E-mail: etc.biodiversity@mnhn.fr
Website: http://bd.eionet.europa.eu

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1 Summary

Although a floristic approach was considered appropriate for the revision of EUNIS terrestrial habitats, which are largely defined by their vegetation, a different approach was considered for EUNIS freshwater habitats. These habitats are characterized by more groups of organisms, like e.g. macroinvertebrates, fish and algae. In the context of the discussion about the revision of EUNIS freshwater habitats, this reports compares the most important freshwater typologies as existing in Europe.

First of all the report explains why a review of the EUNIS freshwater habitats is needed. Then it describes which typologies for freshwater habitats are currently used by EU directives and guidelines and could be added to, or contribute to the EUNIS classification system. It discusses what are the pros and cons of taking the EU habitat Red List typology based on EUNIS-3 habitats for the revision of the EUNIS typology. Furthermore it lists which data are available for freshwater habitats in addition to vegetation data. The report concludes with recommendations on how to proceed.

2 Introduction

The EUNIS habitat classification is a comprehensive and extensive pan-European reference system to harmonize and facilitate the description and collection of data across Europe through the use of criteria for habitat identification (Davies and Moss 1999; Davies et al., 2004; Moss 2008). It is hierarchical and covers all types of habitat types from natural to artificial, from terrestrial to freshwater and marine. At present EUNIS is used for implementing the Marine Strategy Framework Directive but is not directly used for the implementation of the EU Nature Directives. It is also used for the Emerald Network under the Bern Convention. Cross linkages have enabled users of other habitat classifications to relate their national schemes to the international level, in particular to the Annex I habitats of the EU Habitats Directive (Schaminee et al. 2012).

In the EUNIS habitat classification (Davies et al., 2004), the inland surface waters are included as a separate category at level 1 (Group C – Inland surface waters). They are defined as non-coastal, above-ground, open fresh or brackish water bodies (e.g. rivers, streams, lakes and pools, springs), including their littoral zones. They also include constructed inland freshwater, brackish or saline waterbodies (such as canals, ponds, etc.), which support a semi-natural community of both plants and animals, and seasonal waterbodies, which may dry out for part of the year (temporary or intermittent rivers and lakes and their littoral zones). Freshwater littoral zones include those parts of banks or shores that are sufficiently and frequently inundated to prevent the formation of closed terrestrial vegetation. The inland surface waters comprise surface standing waters (C1 types), surface running waters (C2 types) and littoral zones of surface water bodies (C3 types). The several types have been defined in terms of vegetation units (alliances) as defined in the EuroVeg list of syntaxa (Mucina et al., in press). Some EUNIS subtypes of aquatic terrestrial water bodies are totally without vegetation, such as streams and lakes developed below glaciers or ice sheets (C2.23); most of such types are classified under Group H (Inland unvegetated or sparsely vegetated habitats).

For the European Environment Agency (EEA), the revision of EUNIS is currently being undertaken for marine habitats (EUNIS section A), forests (EUNIS G, Schaminée et al., 2013) and for tundra, heaths and scrubland (EUNIS F, Schaminée et al., 2014) and work on grasslands (EUNIS E) has started in 2016. The revision of the EUNIS freshwater C-types has been planned for 2017 or later. This work is making extensive use of phytosociological data, now available from initiatives such as the European Vegetation Archive (EVA, Chytrý et al., 2016; see http://euroveg.org/eva-database). However, there are many classifications of rivers and lakes used in Europe which are not based on floristics and it was considered necessary to examine other possible sources of information relevant to any revision of section C of the EUNIS habitats classification.

Meanwhile, it has become clear that the EU habitat Red List typology based on EUNIS-3 habitats will be important for the revision of the EUNIS typology (Rodwell et al., 2013; Janssen et al 2016). Therefore, this typology will be explored in the next paragraph and is elaborated in Table 2, where the most important freshwater typologies are compared. In the context of the discussion about the revision of EUNIS for freshwater habitats, the following questions have been raised and are explored in this scoping paper focusing on freshwater habitats:

- Why is a review of the EUNIS freshwater habitats needed?
- Which typologies for freshwater habitats are currently being used by EU directives and guidelines and could be added to, or contribute to the EUNIS classification system?
- What are the pros and cons of taking the EU habitat Red List typology based on EUNIS-3 habitats for the revision of the EUNIS typology?
- Which data are available for freshwater habitats in addition to vegetation data?
- Is the classification suitable for use as a habitats reference list for INSPIRE ?
- Recommendations on how to proceed?

3 European Union typologies for freshwater habitats

3.1 Freshwater habitats

Freshwater habitats have a number of characteristics that are, to some extent, more pronounced compared to terrestrial habitats. Firstly, freshwater communities may consist of a large range of populations which are highly dependent on each other within their physical habitat, ranging from macro-invertebrates to plankton, fish, amphibians and aquatic primary producers. Among the aquatic primary producers, including algae and higher plants (macrophytes), the higher plants have a wide variety of growth forms, ranging from sediment-rooted, submerged macrophytes to sediment-rooted, emergent macrophytes, non-sediment rooted submerged macrophytes, sediment-rooted floating macrophytes and free-floating macrophytes (Figure 1). These growth forms already show that aquatic macrophytes use their environment in different ways, in conjunction with the main compartment they are getting their nutrients from (water, sediment, air). This leads to a layered vegetation composed of different growth forms, extending in one or more of the compartments of the water body, i.e. water layer, underwater sediment and/or air above the water. Aquatic macrophytes have important functional and structural roles in aquatic ecosystems (Wetzel, 2001). They form the structure of a freshwater community, the physical framework, providing biotopes for other organisms (zooplankton, phytoplankton, fish, macro-invertebrates; epiphyton, etc.).

Figure 1: Macrophytes show a high variety of growth forms. From left to right: a) flowering sediment-rooted, emergent macrophyte and free-floating macrophytes on top of the water layer; b) sediment-rooted floating macrophytes; c) sediment-rooted macrophytes with submerged and floating leaves d) sediment-rooted, submerged macrophytes

Aquatic macrophytes show a broad plasticity, i.e. they easily adapt to their environment. For instance when water levels drop and water systems are running dry, many submerged macrophytes may easily adapt a terrestrial growth form, like a small rosette or a tuft of leaves. These so-called amphibious plants develop leaves that have stomata and are therefore adapted to a terrestrial life stage. When flooded again, they develop a submerged growth-form. They may also change their physiological regime for mineral and nutrient uptake. Many submerged aquatic macrophytes can easily propagate by stolons or by vegetative shoots, that are transported by water until the shoots find a new place where they will root in the sediment. Some macrophyte species have a short life cycle of a few months at the most, thereby contributing to a high seasonality of the vegetation.

Due to their vegetative propagation, many macrophytes quite often form large monospecific stands. Therefore, most freshwater communities are poor in species. Due to this occurrence in large stands, the vegetation structure takes the appearance of a mosaic. Communities relatively rich in species are mainly those with amphibious plants, e.g. belonging to the class of the *Littorelletea uniflorae* (amphibious plant communities).

Another complicating factor in studying and describing aquatic communities is the fact that in adapting to the aquatic environment many water plants are similar in morphology due to convergent evolution. As a consequence, they are often difficult to distinguish at the species level and therefore show a complex and frequently changing taxonomy, This refers to many of the prevailing genera, such as *Callitriche*, *Lemna*, *Potamogeton*, *Utricularia* and *Ranunculus*.

3.2 Freshwater typologies in the European Union

For freshwater habitats, several typologies are in use across the European Union at the moment. Here, we consider and discuss the EUNIS habitat classification, the list of habitats on Annex I of the Habitat Directive, the Water Framework Directive typology for freshwater habitats and the EU Red List habitat project typology. We do not discuss any of the numerous national typologies here. The CORINE biotope & Palaearctic habitat classifications are considered to have been superseded by the EUNIS classification system and therefore are not considered here separately.

3.3 The EUNIS (European Nature Information System) habitats classification

In the EUNIS habitat classification, a 'habitat' is defined as: 'a place where plants or animals normally live, characterized primarily by its physical features (topography, plant or animal physiognomy, soil characteristics, climate, water quality etc.) and secondarily by the species of plants and animals that live there' (Davies et al., 2004). Habitats are necessarily defined at a given scale. Most but not all EUNIS habitats are in effect 'biotopes', i.e. 'areas with particular environmental conditions that are sufficiently uniform to support a characteristic assemblage of organisms'. In general, the scale selected for the EUNIS habitat classification is that occupied by small vertebrates, large invertebrates, and vascular plants. It is comparable to the scale applied to the classification of vegetation in traditional phytosociology (e.g. Braun-Blanquet, 1928 & Westhoff & Van der Maarel, 1973; Mueller-Dombois & Ellenberg, 1974). All but the smallest EUNIS habitats occupy at least 100 m^2; there is no upper limit to the scale of the largest. At the smaller scale, 'microhabitats' (generally occupying less than 1 m^2 that are important for some smaller invertebrates and lower plants) can be described. At the larger scale, habitats can be grouped as 'habitat complexes', which are frequently-occurring combinations or mosaics of individual habitat types, usually occupying at least 10 ha, which may be inter-dependent.

The EUNIS habitat classification system is integral to policy delivery for DG Environment and widely used by Member States and NGOs in Europe. For terrestrial habitats, EUNIS at level 3 (hereafter,

EUNIS-3) provides units of a practical scale for assessment, intermediate between broadly-defined ecosystems or formations and fine-grained phytosociological syntaxa. Here we have used a crosswalk between EUNIS-3 and the phytosociological syntaxa (alliances) of the EuroVegChecklist as defined in July 2012 (Schaminée et al., 2012) for interpretation and crosswalks to other typologies. The EuroVegChecklist, providing the European overview of syntaxa up to the level of alliances, will be published soon (Mucina et al., 2016). It is integrating the results of many national classification programs (e.g. Rodwell 1991 et seq.; Mucina et al., 1993; Schaminée et al., 1995 et seq.; Valachovič et al., 1995 et seq.; Chytrý 2007 et seq.).

In the EUNIS classification, the criteria used for the classification of lakes are ice-cover, permanence of water body, salinity and trophic status. Criteria used for running waters include permanence, up-welling water, water in thin sheets running over rocks, tidal water and flow, and criteria used for classification of littoral zones, are spray or steam influence, permanence of vegetation, species diversity, substrate, dominance and growth forms. As mentioned before, the freshwater habitats are included in group C of the EUNIS classification and that is the focus of this paper.

3.4 Habitat Directive (HD)

The EU Habitats and Birds Directive form the cornerstones of European legislation on nature conservation. The aim of these Directives is to assure the long-term survival of Europe's most valuable and threatened species and habitats at the European level. The directives have two components – species protection and site protection; The latter is implemented by the Natura 2000 network, which is comprised of Special Areas of Conservation (SAC) designated by Member States under the Habitats Directive and also incorporates Special Protection Areas (SPAs) which are designated under the 1979 Birds Directive. The directive was adopted in order to fulfil obligations under the Bern Convention. For reporting and other assessments, Europe has been divided into nine biogeographical regions.

Sites must be proposed, and if accepted, designated and managed for habitats listed in Annex I and species listed on Annex II of the Habitats Directive. Annex I lists over 230 habitats, including 10 freshwater standing water habitats and 10 freshwater running habitats together with a small number of wetland habitats which EUNIS considers as freshwater (e.g. petrifying springs). The Habitats Directive includes both very broad freshwater habitats and very narrowly occurring and specific freshwater habitats. Actually, the habitats listed in Annex 1 of the Habitats Directive represent a selection taken from a variety of typologies and does not cover all freshwater types in Europe (Evans, 2006). Article 11 of the Habitats Directive requires Member States to monitor the habitats and species listed in the annexes (habitats in the Annex I and species in the Annexes II, IV and V). Article 17 requires a report including an assessment of the conservation status of the habitats and species targeted by the directive. The assessment is made based on information on status and trends of species populations or habitats and on information on main pressures and threats. Article 17 reports also include a map of habitat or species distributions (mapped in 10x10 km grid).

3.5 Water Framework Directive (WFD)

The EU Water Framework Directive (WFD) (EC, 2000) aims at a good ecological status of all water bodies in rivers, lakes and coastal waters based on biological quality elements defined as different groups of aquatic organisms (phytoplankton, phytobenthos, macrophytes, macroinvertebrates, fish) and supporting physico-chemical quality elements (e.g. nutrients, organic matter, oxygen, etc.; European Commission, 2000). Member States have to report the ecological status to the European Commission for the WFD water bodies they have defined in their country. Those WFD water bodies have to meet a minimal size of 50 ha for lakes and 10 km for rivers. Different water types might be aggregated into one water body which are defined based on a hierarchical typology of abiotic conditions (WFD Annex II), e.g. climate (altitude), geology, size and/or morphology, soil and sediment,

and water quality. The WFD assessment defines good ecological status as slight deviations from reference conditions. The reference conditions are defined as the status of a water body with minimal human pressures, where the biological quality elements and the supporting physic-chemical quality elements are in their natural or pristine state.

The WFD typology class boundaries have been intercalibrated between member states in order to compare and fine-tune the national assessments. For this reason, member states have been grouped into Geographical Intercalibration Groups (GIGs) where they agreed on a limited number of common types of water bodies (IC types). The typology for these IC types has been based upon a limited number of abiotic characteristics. Each of the IC types represents several national WFD types from countries within each GIG, having related typology factors and comparable ranges or categories for each factor. The intercalibration process has now been completed for most of the biological quality elements in rivers and lakes (https://circabc.europa.eu/faces/jsp/extension/wai/navigation/container.jsp for Technical reports; see also European Commission 2013). The common intercalibration types are listed for each geographical intercalibration region (GIG) in the IC Official intercalibration Decision document (EC, 2013; http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013D0480).

Due to these differences in assessment systems of the WFD and HD, the ecological status of water bodies under the WFD and under the habitat assessments of Conservation Status under Article 17 of the HD are not comparative in terms of assessment criteria. The EUNIS system might help to bridge this gap. For the WFD, Member States have defined their WFD water bodies at the national level. As a result of these processes, many national typologies co-exist. Those national typologies are not very helpful for revising classifications at the European level, e.g. EUNIS. However, many large national WFD types have high similarity and may be aggregated into 20 broad river types and 15 broad lake types based on altitude, size and geology (and mean depth for lakes) (ETC/ICM, 2015; Kristensen, 2016). More concern is with the small water bodies, which very much depend on national typologies (Kristensen, 2016).

3.6 EU Red List habitat project typology

The EU habitat Red List project (Janssen et al., 2014, 2016) has delivered a Red List assessment of European habitat types according to a slightly modified version of the IUCN methodology (criteria and categories) recommended in the EC feasibility study (Rodwell et al., 2013). This is largely compatible with the methodology proposed by IUCN for Red Listing of ecosystems (Keith et al. 2013). The typology used in the EU Red List habitat project is based on EUNIS-3 habitats (Davies et al., 2004), with some modifications. Based on the already mentioned feasibility study, it was concluded that the mid-scale of habitats (EUNIS-3) is the most practicable typology for Europe. The EUNIS Habitat Classification has the great advantage of providing a single framework for the marine as well as the terrestrial and freshwater habitats at an European scale. It is moreover fully compatible with the typology of the MAES (Mapping and Assessment of Ecosystems and their Services project as part of the EU 2010 Biodiversity Baseline. For defining the Red List habitats, the crosswalk between EUNIS-3 and the phytosociological syntaxa of the EuroVegChecklist (July 2012) has been used (Schaminée et al., 2012). Those alliances equivalent to each of the Red List habitats are listed as part of the description. The EU red list project has also provided Red List assessments for all habitats included in Annex I of the Habitats Directive.

The EU habitat Red List typology based on EUNIS-3 habitats will be the starting point for the planned revision of the EUNIS typology for freshwater habitats. Therefore, this typology will be explored in the next paragraph and is elaborated in Table 2, where the most important freshwater typologies are compared.

3.7 Crosswalks between typologies

So far, several crosswalks have been published between typologies as defined within different EU directives and other typologies. ETC/ICM (2015) published a crosswalk between the Water Framework Directive and the Habitats Directive and the EEA has published a crosswalk between Annex 1 and several other typologies or classifications including EUNIS[1] Here we consider the EUNIS-3 levels, as this level is most appropriate for an adequate coupling with vegetation units (alliances).

The typologies described above (sections 2.2-2.6) differ in their approach. The EUNIS freshwater and WFD typologies are hierarchical systems of abiotic conditions (Table 1). The WFD water body typology is national oriented and differs per country. Therefore, there is not 'one' single WFD typology. The broader IC types might be representative for the larger lakes and rivers at the European level. Table 1, however, shows that the abiotic conditions used in both typologies differ from each other. The EUNIS system is focused on trophic status, while the WFD broader typology considers alkalinity and calcium as the most important and determinant factors. In contrast, the Habitat Directive does not apply an abiotic approach but instead defines habitat types covering a selection of habitats that are of specific conservation value at the European level. Those habitats are mostly taken from the CORINE biotopes typology and are based on a floristic approach. The EU Red List habitat project typology integrates the EUNIS habitats with the Habitat Directive habitat types.

Table 1: Abiotic conditions used for hierarchical typologies of EUNIS freshwater and WFD IC types

Lakes		**Rivers**	
EUNIS	**WFD broad / IC types**	**EUNIS**	**WFD broad / IC types**
ice-cover	Altitude	Permanence	Altitude
permanence of water body	surface area	up-welling water	catchment size
Salinity	geology (alkalinity, calcium, colour, bedrock)	water in thin sheets running over rocks	geology (alkalinity, calcium, colour, bedrock)
trophic status	mean depth	tidal water	
		Flow	

Merging distinct typologies is only possible when focusing on the broader habitats at the higher levels of each hierarchy. ETC/ICM (2015) uses three methodologies to define broader types, that allow comparison between the national WFD types for lakes and rivers with the HD types for standing and running waters. The first methodology uses a conceptual, theoretical approach. The second methodology uses the European catchments and rivers network system (ECRINS; Nixon et al. 2012) as a basis. The third and most promising was to define typology factors and categories for each factor. For lakes they used altitude, surface area, geology and mean depth (Table 1). For rivers they used altitude, catchment and geology (Table 1). The ecologically most relevant combinations of these typology factors gave 20 broad river types and 15 broad lake types (ETC/ICM, 2015). In a subsequent step, the national WFD water bodies were linked to these broader lake and river types. The WFD

[1] http://www.eea.europa.eu/themes/biodiversity/eunis/eunis-habitat-classification#tab-documents

ecological status and pressures of water bodies reported by Member States in their first River Basin Management Plans could then be aggregated to the broader lake and river types.

In order to link WFD and HD habitats, several assumptions were made by the authors (ETC/ICM, 2015). As the WFD uses geology expressed as calcium or alkalinity in its typology, while the HD uses natural trophic status to characterize the freshwater habitats for standing waters, those systems needed to be aligned. Therefore, the authors made the assumption that the HD/EUNIS terminology oligotrophic, mesotrophic and eutrophic refers to natural trophic state, and that these trophic state terms matches the WFD terminology low, moderate and high alkalinity types, respectively. In our view, these assumptions are oversimplified and might be considered as a very rough approximation. They also assumed that the oligo- and mesotrophic habitat types are mostly either deep or shallow, whereas the naturally eutrophic lakes are mostly shallow or very shallow, using the WFD Annex II depth categories. Also these assumptions are considered as a very rough approach.

Table 2 presents a possible integration of WFD, HD and EUNIS habitat types and the revised EUNIS types from the EU Red List habitat project. This integration is based on the work of the Freshwater Group of the EU Red List habitat project (Janssen et al., 2016; Gertie Arts participates in this group) and the work of ETC/ICM (2015).

From a floristic and phytosociological point of view, the typologies differ in their approach. EUNIS-3 and the Habitat Directive are based on a phytosociological approach. EUNIS-3 operates at the level of vegetation alliances. The habitats in the Habitats Directive are based on phytosociological units as well, mainly at the level of alliances and associations. The WFD is not based on such a phytosociological approach, but merely on a floristic approach. Characteristic macrophyte species (in some countries derived from characteristic plant communities) are deduced for the reference class for each WFD type. These characteristic species are quantified in metrics for the different WFD types. Some countries have chosen the approach of macrophyte metrics including characteristic species as well as species indicating deterioration of the habitat. The EU Red List habitat project typology integrates the EUNIS habitats with the Habitat Directive habitat types and considered phytosociological alliances.

The EUNIS-3 level represents a more specific and more detailed level than the level of the larger rivers and lakes as is shown in Table 2. As this typology is at the level of alliances, there is a direct connection to the vegetation-typology of freshwater systems. This level is therefore the most appropriate to link water quality in freshwater systems (in the broadest sense including all biological data in freshwater systems) to vegetation data. Databases like EVA are very important in this respect.

3.8 Available Information and data

Broader types of rivers and lakes can be used to aggregate information on status and pressures/threats reported by Member States under the two directives for water bodies, i.e. national WFD water bodies and HD freshwater habitats. Also at the level of floristic data, an integration might be possible at this level, although WFD and HD approaches are different (see section. 2.6).

The WISE-WFD database contains data from River Basin Management Plans reported by EU Members States according to article 13 of the Water Framework Directive. The habitat directive Article 17 database from 2006, and later, include HD habitat data. In the context of the WFD, Member States need to report the status of phytoplankton (= floating algae in the water layer), phytobenthos (= algae attached on surfaces and sediment), macrophytes, macroinvertebrates and fish and physico-chemical data such as nutrients, organic matter, and oxygen. WFD data are not vegetation typology or phytosociologically oriented and only report the outcome of macrophyte metrices based on the abundance of characteristic and nuisance species. On the other hand, HD freshwater habitats often lack abiotic data (e.g. water quality) data which can be completed by WFD data (approach followed

by ETC/ICM (2015)). However**,** HD habitats often form a subset of WFD lakes and rivers. Also, HD habitats need stricter abiotic conditions (water quality, habitat morphology, hydrology) for sustaining the habitat communities and ecosystems that are under protection. Therefore, this aggregation of information need to be checked for Natura 2000 sites and countries, and review is needed to check the approach is adequate. There is a reasonable match between the WFD broad types, the WFD intercalibration common types and the HD freshwater habitat types, as well as EUNIS types for both rivers and lakes, with the exception of two very wide HD river habitats, the HD type 3260 rivers from plain to montane levels, and 3210 Fennoscandian rivers, as well as some very narrow HD and EUNIS types (Kristensen, 2016). Besides the WFD databases of Member States, Member States have cooperated in the intercalibration of broader lake and river types and these data enable a second source of WFD data (European Commission, 2013).

At the Member States level, data on water quality, phytoplankton and macroinvertebrates are present in national data files of the relevant authorities (e.g. waterboards in The Netherlands). For example, this is the case for EUNIS lake types C1.1-C1.4. If available, these data can be used for adding to habitat descriptions in EUNIS or the European red list of habitats.

Several databases already exist at the European level, like the European Vegetation Archive (EVA), databases and maps build in the EU project of the EU red list habitats for DG/ENV, WFD assessments and inter-calibration databases, HD freshwater habitat Article 17 assessments. These databases need to be integrated and applied, e.g. in the generation of suitability maps for EUNIS freshwater types over Europe.

3.9 Conclusions from crosswalks between different typologies

In this scoping paper the most important freshwater typologies are compared and explored in the context of the discussion about the revision of EUNIS for freshwater habitats. Having explored these typologies, the main conclusions can be summarized as follows:

1. The EUNIS-level 3 is the most appropriate level for classification of freshwater systems. At this level an adequate coupling of biotic (vegetation, faunal community) and abiotic (water quality) information is feasible and promising;
2. The EUNIS-level 3 is also appropriate to include the smaller streams and lakes (e.g. small soft-water lakes) that currently fall out of the WFD water body typology or are merged into the larger water bodies and therefore 'hidden' in the WFD classification system;
3. The EUNIS-3 level freshwater systems represents a more specific and more detailed level than the level of the larger rivers and lakes (see Table 2);
4. There are some EUNIS river habitats that are more specific and narrow than any of the broad types (Table 2); however, it is also the other way around, e.g. the C2.3 EUNIS habitat type (Permanent non-tidal, smooth-flowing watercourses) is very broad and covers all lowland river types).
5. There are some EUNIS lake habitat types not matching WFD lake types (Table 2);
6. Possible integration of WFD, HD, and the revised EUNIS freshwater habitat types as used in the EU Red List habitat project is presented in Table 2. This exercise shows that at the lower levels the systems do not match and refinements are needed. A revised EUNIS system could address this issue.
7. A revised EUNIS typology as used in the EU red list project is a first step forward to a revised and more appropriate freshwater typology at the European scale.

4 Recommendations on how to proceed

4.1 Inventory of databases

A revised EUNIS typology for freshwater habitats needs to be based on data. At the European level several databases are available. In order to proceed, and as a first step, it is recommended to explore, connect and use Europe wide databases, such as:

- European Vegetation Archive (see http://euroveg.org/eva-database);
- Databases and maps build in the EU project of the EU Red List habitats for DG/ENV;
- WFD inter-calibration databases;
- WFD freshwater assessments;
- HD freshwater habitat Article 17 assessments;
- EU Red List databases.

Connection of these databases, preferably at the level of alliances, can contribute to a revised and improved EUNIS typology for freshwater, building upon the revised EUNIS-level-3 typology as used in the EU Red List project and building upon Table 2. Connected data might be used to generate suitability maps for freshwater habitats in Europe. It is recommended to start with two pilot studies to develop an appropriate methodology and to evaluate the feasibility of the approach, e.g. one in The Netherlands and one in Czech Republic.

4.2 Actions underpinning a revised EUNIS typology

Here we propose a number of recommendations in the form of a list of more detailed actions describing the next steps to be taken to a revised EUNIS typology:

1. The EUNIS river habitat types need better definitions and it is recommended to refine the typology and add missing river habitats (e.g. mid-altitude river types); this can be achieved and underpinned by the databases collected and connected. The Red List project did not optimize the EUNIS river habitat types.
2. A second priority is to explore how the EUNIS-3 level habitats can be linked to the EU common intercalibration types. These common intercalibration types are more specific than the broad river and lake types and are more similar to the level of the EUNIS-3 habitats. However, a first glance at this shows it might work for the lakes but not for the rivers. Therefore, the EUNIS river habitat types first need more specification and it is recommended to refine the typology for the rivers.
3. At the European level, it should be explored if the EUNIS types could benefit from floristic and vegetation descriptions and data from WFD and HD typologies. In line with the former work on forests (2013), tundra, heath and shrublands (2014), and grasslands (2015-2016), a project must be addressed to couple and underpin the EUNIS aquatic habitat types with the European vegetation data at the level of alliances. Important input for this will be provided by the EC Red List project on habitat types.
4. The EUNIS-3 level river habitat types that are too broad need to be divided into more specific river types, e.g. habitat C2.3 could be split up in upper, middle and lower river stretches and described in types at the EUNIS-3 level. Here EUNIS can benefit from the WFD typology.
5. The more specific EUNIS-3 level habitats that cover rare and rather unique habitats could be linked to specific habitats of EU Member States, as these habitats are specific and often limited to one or two EU Member States. Therefore, it is expected that these definitions can be improved using information at the national level, e.g. information from the HD.

Although the recommendations above are listed in a range of priorities, we have the opinion that revision of the freshwater section of the EUNIS habitat classification is only fully accomplished if all recommendations have been addressed.

It is recommended to establish an European working group, led by Alterra and including European EUNIS, WFD and HD experts. This working group should be multi-disciplinary and include several fields of expertise (aquatic ecologists, phytosociologists, vegetation ecologists). This working group should include representatives from different regions of Europe. Working from one or two workshops, this group can establish the principles for a revision, use them to produce a draft and send this out for consultation followed by a final revision.

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Table 2: DRAFT table presenting a possible integration of WFD, HD and EUNIS habitat types based on the work of the Freshwater Group of the EU Red List habitat project and the EU broad lake and river typology published by ETC/ICM (2015). EUNIS units ending in a or b are proposed new units as used for the Red List project and assessments

N°	EUNIS type	HD Habitat type code	Description of EUNIS type	Equivalent EUNIS type(s)	Broad lake / river type (ETC/ICM, 2015)
1	C1.1a	3110	Permanent oligotrophic waters with very soft-water species		2. Lowland, silicious 7. Mid-altitude, silicious 11. Highland, siliceous
2	C1.1b	3130	Permanent oligotrophic to mesotrophic waters with soft-water species		2. Lowland, silicious 7. Mid-altitude, silicious 11. Highland, siliceous
3		3130	Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoeto-Nanojuncetea	C1.1a, C1.1b and C3.5b	3. Lowland, calcareous/mixed, stratified 8. Mid altitude, calcareous/mixed
4	C1.2a	3140	Oligotrophic to mesotrophic waters with Characeae [Charetea fragilis]		3. Lowland, calcareous/mixed, stratified 8. Mid altitude, calcareous/mixed
5	C1.2b		Mesotrophic to eutrophic waters with floating and/or submerged angiosperms		3. Lowland, calcareous/mixed, stratified 8. Mid altitude, calcareous/mixed
6		3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition -type vegetation	C1.2b	4. Lowland, calcareous/mixed, very shallow/unstratified
7		31A0	Transylvanian hot-spring lotus beds	C1.2b	
8	C1.4	3160	Permanent dystrophic waters		5. Lowland, organic (humic) and silicious 6. Lowland, organic (humic) and calcareous/mixed

9	C1.5		Permanent inland saline and brackish waters		
10	C1.6a		Temperate temporary waters		
11		3180	Turloughs	C1.6a	
12		3190	Lakes of gypsum karst	C1.6a	
13	C1.6b	3170	Mediterranean-Atlantic temporary waters		15. Mediterranean, very small
		3170	Mediterranean temporary ponds	C1.6b	15. Mediterranean, very small
32		3120	Oligothrophic waters containing very few minerals generally on sandy soils of the West Mediterranean, with Isoetes spp	C1.6b	13. Mediterranean, small-large, siliceous (incl reservoirs)
14	C1.7		Permanent lakes of glaciers and ice sheets		
15	C2.1a		Base-poor springs and spring brooks		
16		7160	Fennoscandian mineral-rich springs and springfens	C2.1a	
17	C2.1b		Calcareous springs, spring brooks and tufa cascades of karstic rivers		
18		32A0	Tufa cascades of karstic rivers of the Dinaric Alps	C2.1b	
19		7220	Petrifying springs with tufa formation (Cratoneurion)	C2.1b	
20	C2.2a		Permanent non-tidal, fast, turbulent watercourses of montane to alpine regions with moss communities		14. Highland (all Europe), siliceous 15. Highland (all Europe), calcareous/mixed
21	C2.2b		Permanent non-tidal fast, turbulent watercourses of plains and mountain regions with Ranunculus ssp		14. Highland (all Europe), siliceous 15. Highland (all Europe), calcareous/mixed

22		3260	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation	C2.1b and C2.3	1. Very large rivers (all Europe) 2. Lowland, siliceous, medium large 6. Lowland, organic and siliceous 7. Lowland, organic and calcareous/mixed 3. Lowland, siliceous, very small-small 4. Lowland, calcareous or mixed, medium-large 5. Lowland, calcareous or mixed, very small -small
23	C2.3		Permanent non-tidal, smooth-flowing watercourses		1. Very large rivers (all Europe) 2. Lowland, siliceous, medium large 6. Lowland, organic and siliceous 7. Lowland, organic and calcareous/mixed 3. Lowland, siliceous, very small-small 4. Lowland, calcareous or mixed, medium-large 5. Lowland, calcareous or mixed, very small -small
24	C2.4		Tidal rivers, upstream from the estuary		
25	C2.5a		Temperate temporary running waters		