



# Toponyms: a neglected asset within the water framework and flood directives implementation process; the case study of Greece

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## Abstract

Proxy data and qualitative information are important assets in water resources and floods management. In the research, the river water bodies with characteristic toponyms (hydronyms) in Greece that potentially reflect the water's quality or the occurrence of floods are evaluated in comparison to the European Union's (EU) Water Framework and Flood Directives implementation process outputs. For doing so, after identifying the river water bodies with characteristic toponyms which form the 10.2% of the Greek water bodies, the toponyms are cross correlated with the water bodies quality status as retrieved by the Directives' databases to validate the existence of linkages between the names and the quality. Similarly, the significant floods, as derived from the Flood Directive, are spatially allied with the water bodies with characteristic toponyms to ground truth the connection between significant floods and water bodies whose toponyms imply flood prone areas. The research outputs indicate a high degree of correlation both in terms of water quality and floods, meaning that in almost all cases the water body toponym depicts the good or bad quality of the water body or the occurrence of flood events. Moreover, it is established that almost 90% of the water bodies with characteristic names are intermittent and ephemeral ones. The water bodies' toponyms, hence, are proposed as an auxiliary criterion during the Directives implementation process that could foster increased water quality and flood-related knowledge, especially in intermittent and ephemeral water bodies which are generally lacking observations, and can be applied not only in all EU-Member States' waters, but also in global scale.

**Keywords** Hydronyms · Toponyms · Water bodies · Water framework directive · Floods directive · Water and floods management

## Introduction

Toponyms are an important data source that reflect the human activities and natural landscapes within a certain area and time period (Zhong et al. 2020). For example, Luo et al. (2010) quantitatively present the relationship between Tai toponyms and terrain characteristics which are used for wet rice farming, or Kharusi and Salman (2015) explore the Arabic terms related to fresh water sources expressed in Oman's toponyms and demonstrate that the significance of scarce water resources in dry environments is expressed

through toponyms. Frajer and Fiedor (2018) use place names in a GIS environment for the identification and spatial distribution of disappeared water bodies that used to serve as fishponds and were converted into arable lands in the past. The authors conclude that areas linked to fishpond extinction are now facing more frequent droughts. Other scholars use the hydronym information to trace the parent channels of the study rivers and validate the hydrographic network (Sah et al. 2022). The most indicative example of hydronyms expressing a river's characteristics are the Blue and White Nile Rivers, since the latter's name stems from the light gray sediments that it carries while Blue Nile's name is attributed to the water dark reddish-brown muddy colour because of the type of sediments it contains (Vijverberg et al. 2009). Nevertheless, linkages between the hydronyms, hereinafter expressed as toponyms, and the water quality and quantity (mainly regarding floods) are rather limited in the literature.

At the European Union (EU) scale, the water related policies, such as the Water Framework and Floods Directives,

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that have gradually been put in force since the beginning of the twenty-first century consist of the most holistic, modern, and up-to-date policy frameworks regarding water resources management. The protection of the water resources, as well as securing human lives and activities against extreme events are the core elements of the Directives, which are also gradually being adopted in several non-EU countries (e.g. Ergönül et al. 2018; Zhou et al. 2014). Focusing on the Water Framework Directive (WFD) (EC 2000) that fosters the good quality of the water bodies, i.e. of designated water units that a hydrographic system is composed of (EC 2003a), its' operational implementation process is conducted through the River Basin Management Plans (RBMPs). These strategic documents, which have a rolling 6-years life cycle, integrate all the available information and data coming from common monitoring programmes and protocols for all the EU Member-States (EC 2003b) about the quality status of all water types, e.g. surface, groundwater, transitional and coastal waters, at basin scale, resulting in the classification of the water bodies quality, and thus the characterization of the waters' quality. In cases where a good quality status, which is the principal aim the Directive, is not achieved, specific measures for the amelioration of the degraded water bodies status are proposed in the RBMPs with the effectiveness of these measures to be evaluated in the upcoming RBMPs (e.g. EC 2021). The advantages and bottlenecks of the WFD implementation process are thoroughly discussed within the literature (Skoulidakis et al. 2021; Skoulikaris 2021; Vito et al. 2020; Carvalho et al. 2019; Maia 2017; Voulvoulis et al. 2017; Parés et al. 2015).

On the other hand, the Directive on the Assessment and Management of Flood Risks (EC 2007), commonly known as the Floods Directive (FD), focuses on reducing and managing the risks of potential floods to human health, environment, cultural heritage and economic activities (Nones 2019). The implementation of the FD is conducted through three sequential steps, namely: (i) the preliminary flood risk assessment aiming at producing areas of potential significant flood risks (APSF) as a spatial compilation of historical significant flood events, of infrastructures and locations of significant importance, and of terrain slope characteristics; (ii) the development of flood hazard maps through hydrologic and hydraulic modeling within the APSF, and of flood risk maps which are produced on the basis of the hazard maps and expressed in terms of potential number of inhabitants affected, economic activity damaged and degraded environmental areas; and (iii) the creation of Flood Risk Management Plans (FRMPs) (Bubec 2016; Nones 2015). FRMPs are those comprehensive documents that integrate the produced information to force protection measures and risk absorption at various levels as well as to enable spatial water governance (Hartmann and Driessen 2017). The whole process is repeated every 6-years to ensure that

flood risk takes account of new information, developments and changes in risk. The gained benefits and the shortcomings on achieving FD objectives and management of flood risks are peer reviewed by various scholars (Goytia 2021; Brillinger et al. 2020; Hartmann and Spit 2016; Tsakiris 2014; Heintz et al. 2012).

Apart from the public and stakeholders' participation in the implementation process of the WFD and FD, which is a particular pioneering issue (Ruiz-Villaverde and García-Rubio 2017; Jager et al. 2016), the fact that both Directives are developed within the same reference scale, i.e. the River Basin District (RBD), is also considered one of the Directives innovations. Based on recent data, the fitness check at the functioning of and relationship between the FD and WFD demonstrated that the interactions are positive and lead to synergies (Vermeulen et al. 2019), while other scholars, e.g. Skoulikaris and Krestenitis (2020), investigate the coupling of the WFD with other EU Directives for accurate water balance modelling. Going a step forward, it can be said that the water bodies are the cornerstone of the implementation process of both Directives, since they both use the same delineated water bodies. Particularly, in the WFD the pressures analysis, the water quality and the proposed measures are directly connected to the designated water bodies, while in the FD the floods' occurrence assessment and the flood hazards simulation is conducted on water bodies. However, and to the author's knowledge, qualitative characteristics of the water bodies, such as their names (toponyms) have not been taken into consideration during the implementation of the Directives.

The research's objective is to investigate in which way the water bodies' names, i.e. their toponyms (or hydronyms), could provide a priori evidences about the water quality and the floods occurrence locations, and by what means these evidences could facilitate the WFD and FD implementation processes, respectively. For this purpose, the delineated water bodies together with their quality characteristics as well as the significant floods were retrieved from official EU databases storing the Directives' produced datasets. The water bodies with characteristic toponyms indicating good or bad water quality and flood incidents were identified. Their quality status, as retrieved from the databases, was assessed in comparison to their toponyms to validate potential linkages. Similarly, the recorded significant floods were spatially associated with the water bodies with characteristic toponyms to inspect any connections between the floods and the toponyms. Apart from the correlation investigation, the outputs on the water bodies with characteristic toponyms are compared with the sum of the water bodies' characteristics and of the significant floods in Greece, which is the case study area. The research outputs could be used as validation proxies in the implementation of water resources management frameworks at River Basin District scale.

## Methodology

### Background information and utilized data sources

The characterization of the water quality in WFD implementation process is based on the outputs of a standardized monitoring programme (EC 2003b) which feeds the two "indicators", namely the ecological status and the chemical status, that determine the surface water quality. Ecological status is related to the ecosystems health and is expressed by: (i) biological quality elements, such as phytoplankton, other aquatic flora, macroalgae, angiosperms, macrophytes, phyto-benthos, benthic invertebrate fauna and fish; (ii) hydromorphological elements, such as hydrological regime, river continuity conditions and morphological conditions; and (iii) physico-chemical elements such as nutrient, oxygenation, thermal, transparency, salinity conditions, acidification status and river basin-specific pollutants (EEA 2018). To that end, a water's body overall ecological status classification as high, good, moderate, poor, bad and unknown, is determined per each element, however, the element with the worst status dominates the final characterization, i.e. the "one out, all out" principle (Zacharias et al. 2020). The water bodies' chemical status categorization as good or bad depends on the concentrations of certain pollutants (45 in total), known as priority substances, such as cadmium, mercury, lead, nickel and their compounds, benzo(a)pyrene, etc. Hence, the attribution of a water body with good chemical status means that no concentrations of priority substances exceed specific Environmental Quality Standards (EQS) established in the EQS Directive 2008/105/EC (EC 2008, 2013).

The significant floods, i.e. floods responsible for either human losses and/or flooded areas > 500 hectares and/or financial compensations > 200.00 € (Hellenic 2019), have an important role in the FD implementation process. They are key elements for the designation of the APSFRs, i.e. the areas where detailed hydrologic and hydraulic modelling is conducted for the simulation of the flood hazard under various return periods. Thus, large number of significant floods events together with sparsely distribution of the events within a river basin implies greater number of water bodies that need to be simulated.

For the articulation of the research, data related to the water bodies, such as their delineation, names, geographic locations, chemical and ecological status, and to the significant floods, such as the coordinates of occurrence, are coming from EU databases that store the official data provided by the EU Member States. Regarding the WFD, the spatial information of the water bodies at each Greek RBD was retrieved from the WISE database (version 1.4), which includes the outputs of 2nd cycle of RBMPs (<https://www.eea.europa.eu/data-and-maps/data/wise-wfd-spatial-3>).

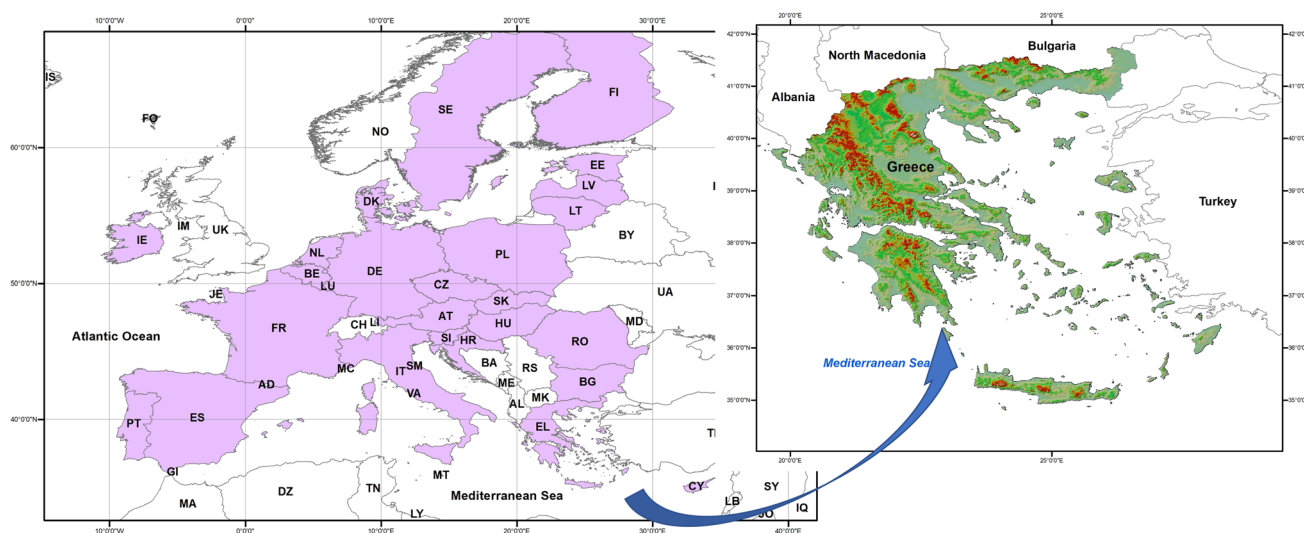
Information on the water bodies' status of 2018, i.e. pressures, ecological and chemical status, were obtained by the corresponding WISE database (<https://www.eea.europa.eu/data-and-maps/data/wisewfd-4>). Finally and regarding the floods, digitized spatial data related to significant floods were obtained from the European Environment Information and Observation Network (EIONET) (<https://cdr.eionet.europa.eu/gr/eu/floods/>) and further processed for the purpose of the research.

### Case study area

Greece is geographically located in the most southern part of the Balkan Peninsula. In its north, and from east to west, it borders with Turkey, Bulgaria, North Macedonia and Albania, while the other parts of the country are surrounded by the Mediterranean Sea, Fig. 1. The country's extent is 131,957 km<sup>2</sup> while its estimated population by the Hellenic Statistical Authority<sup>1</sup> in 2020 was 10,718,565 inhabitants. Greece has been a Member-State (MS) of the EU since 1981, hence it has reformed its national legislation according to the EU laws, Directives and other legislation acts. Focusing on the EU environmental related policies and derived obligations, the WFD and FD were initially ratified as Greece's official water laws in 2003 (Government Gazette 280 A/09.12.2003; Government Gazette 54/A/08.03.2007) and 2010 (Government Gazette 1108/B/21.7.2010), respectively, with continuous amendments to be added since then. In terms of the WFD and FD implementation process progress, currently, Greece has conducted the first revision of the River Basin Management Plans (RBMPs) (since 2017) as well as the initial version of the Flood Risk Management Plans (FRMPs) (since 2018), while the 2nd revision of these strategic plans is scheduled to be finalized by the end of 2023.

According to data from the 1st revision of the RBMPs, in the country there are 1317 designated river water bodies (RWBs) distributed unevenly within its 14 River Basin Districts (RBDs), Table 1. The larger RBD of 13,619 km<sup>2</sup> is the RBD of Western Macedonia (EL09), while the smaller one of 3,186 km<sup>2</sup> is the RBD of Attica (EL06). The RBD

<sup>1</sup> Hellenic Statistical Authority – Estimated Population (1.1.2020) and Migration Flows (2019) [https://www.statistics.gr/en/statistics?p\\_id=documents\\_WAR\\_publicationsportlet\\_INSTANCE\\_qDQ8fBKKo4IN&p\\_p\\_lifecycle=2&p\\_p\\_state=normal&p\\_p\\_mode=view&p\\_p\\_cacheability=cacheLevelPage&p\\_p\\_col\\_id=column-2&p\\_p\\_col\\_count=4&p\\_p\\_col\\_pos=1&\\_documents\\_WAR\\_publicationsportlet\\_INSTANCE\\_qDQ8fBKKo4IN\\_javax.faces.resource=document&\\_documents\\_WAR\\_publicationsportlet\\_INSTANCE\\_qDQ8fBKKo4IN\\_in=downloadResources&\\_documents\\_WAR\\_publicationsportlet\\_INSTANCE\\_qDQ8fBKKo4IN\\_documentID=433647&\\_documents\\_WAR\\_publicationsportlet\\_INSTANCE\\_qDQ8fBKKo4IN\\_locale=en](https://www.statistics.gr/en/statistics?p_id=documents_WAR_publicationsportlet_INSTANCE_qDQ8fBKKo4IN&p_p_lifecycle=2&p_p_state=normal&p_p_mode=view&p_p_cacheability=cacheLevelPage&p_p_col_id=column-2&p_p_col_count=4&p_p_col_pos=1&_documents_WAR_publicationsportlet_INSTANCE_qDQ8fBKKo4IN_javax.faces.resource=document&_documents_WAR_publicationsportlet_INSTANCE_qDQ8fBKKo4IN_in=downloadResources&_documents_WAR_publicationsportlet_INSTANCE_qDQ8fBKKo4IN_documentID=433647&_documents_WAR_publicationsportlet_INSTANCE_qDQ8fBKKo4IN_locale=en)



**Fig. 1** Overview of the geographic location of Greece and illustration of the EU Member-States (purple polygons) overlaid over the European continent

of Thrace (EL12) hosts, in comparison to the other RBDs, the larger number of RWBs, i.e. 177 RWBs, and at the same time the specific RBD presents the higher RWBs' density (i.e. the RWBs' total length divided by the extent of the corresponding RBD) of 15.36%. The lower number of RWBs, in comparison to the other RBDs, i.e. 15 RWBs, as well as the smaller RWBs' density of 3.96%, is found in the RBD EL06.

In terms of water quality characteristics and regarding the chemical status of the RWBs at national level, 89.2%, i.e. 1175 out of 1317 RWBs, have good chemical status, 1.9%, i.e. 25 RWBs, have moderate chemical status, while the chemical status of 8.9% RWBs, i.e. 117 RWBs, is unknown. Focusing on the ecological status, 0.8% of the RWBs, i.e. 11 out of 1317 RWBs, have high ecological status, 62.4%, i.e. 822 out of 1317 RWBs, have good ecological status, 22.7%, i.e. 299 RWBs, have moderate ecological status, while 6.2% and 1.1% of the RWBs are classified with poor and bad ecological status, respectively. Finally, for 6.8% of the RWBs, i.e. 90 out of 1317 RWBs, the ecological status is unknown. The distribution of the chemical and ecological status of the RWBs per RBDs is depicted in Fig. 2.

Regarding the significant flood events, the available data are separated in two time periods, Table 1. The first period, which covers the historic floods of the twentieth century and up to the year 2011, includes a very limited number of significant floods, i.e. 297 floods, due to the lack of an official recording instrument, and thus numerous historic floods might not have been documented. On the other hand, the second period from 2012 to 2018 coincides with the development of an official database for floods' recording and mapping, which is a derivative of the Floods Directive implementation process (EC

2020). Hence, by 2012 and thereafter, all the floods occurring within the Greek territory are recorded in the national floods database by the water-related public authorities, a method that guarantees the accuracy of the recorded floods. During this second period the database has recorded 1953 significant flood events. To avoid any inconsistencies derived from the flood events mapping-recording process over time, the conducted analysis in the research is focused on the data of the period 2012–2018 where these data is recorded in a homogenous reliable way. The distribution of the significant floods for the period 2012–2018 are illustrated in Fig. 3, with the RBDs of Western Peloponnese (EL01), Northern Peloponnese (EL02), Epirus (EL05), and Thrace (EL12) being the ones presenting more than 250 events during the specific time period.

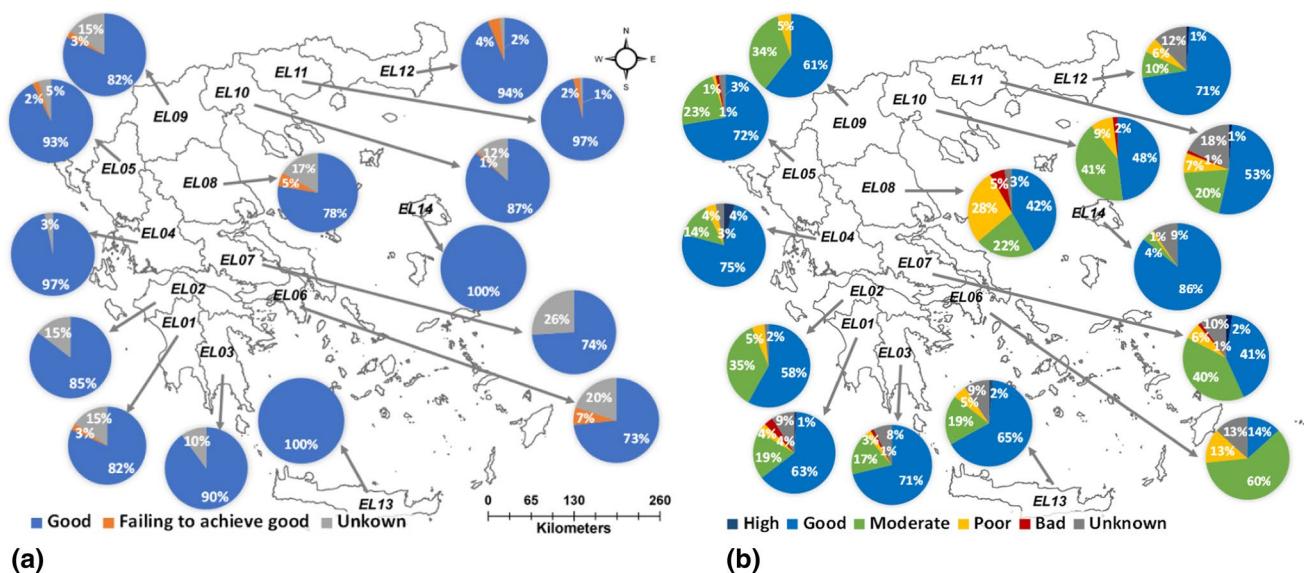
### River water bodies with indicative toponyms

In the research, 134 water bodies, i.e. 10.2% of the national RWBs, with characteristic toponyms, as indicated in Table 2, were selected to be investigated in terms of chemical and ecological status as well as significant flood occurrence sources. In all cases, the Greek name of the RWB was the forcing condition in order to assess the correlation of a water body's name with its water quality and with the floods occurred within or close to it. For accuracy reasons Table 2 contains the original name of the RWB in Greek, its English translation, and the justification for being selected. The 134 RWBs with characteristic toponyms are classified in 14 categories, since in many cases the names of the water bodies were very similar, e.g. "*Μαυρόρεμα*" means Black stream, while "*Μαυροπόταμος*" means Black river. Moreover, a

**Table 1** Characteristics of river water bodies (RWBs) and flood events in the River Basin Districts (RBDs) of Greece

RBDs	RBD's extent (km <sup>2</sup> )	No. of RWBs	Average RWB's length (km)	Total RWB's length (km)	Density (%)*	Significant flood events (until 2011)	Significant flood events (2012–2018)
EL01	7234	110	8.06	886.1	12.25	3	268
EL02	7396	62	10.82	671.2	9.08	7	258
EL03	8442	80	7.09	567.6	6.72	4	113
EL04	10,496	96	10.94	1001.2	9.54	7	107
EL05	9980	83	13.36	1095.9	10.98	15	253
EL06	3186	15	8.40	126.2	3.96	54	77
EL07	12290	81	12.75	1033.0	8.41	40	33
EL08	13141	72	19.27	1387.8	10.56	35	75
EL09	13619	150	10.37	1554.7	11.42	21	160
EL10	10164	104	10.81	1124.8	11.07	40	176
EL11	7320	84	9.96	837.1	11.44	17	25
EL12	11242	177	9.75	1726.5	15.36	18	296
EL13	8344	118	5.61	662.4	7.94	6	51
EL14	9141	85	5.73	487.5	5.33	30	61
SUM	131,995	1317	10.21**	13,162.0	9.97	297	1953

\*The density is defined as RWBs total length divided by the extent of the corresponding RBD; \*\*the specific figure defines the average length of the RWBs

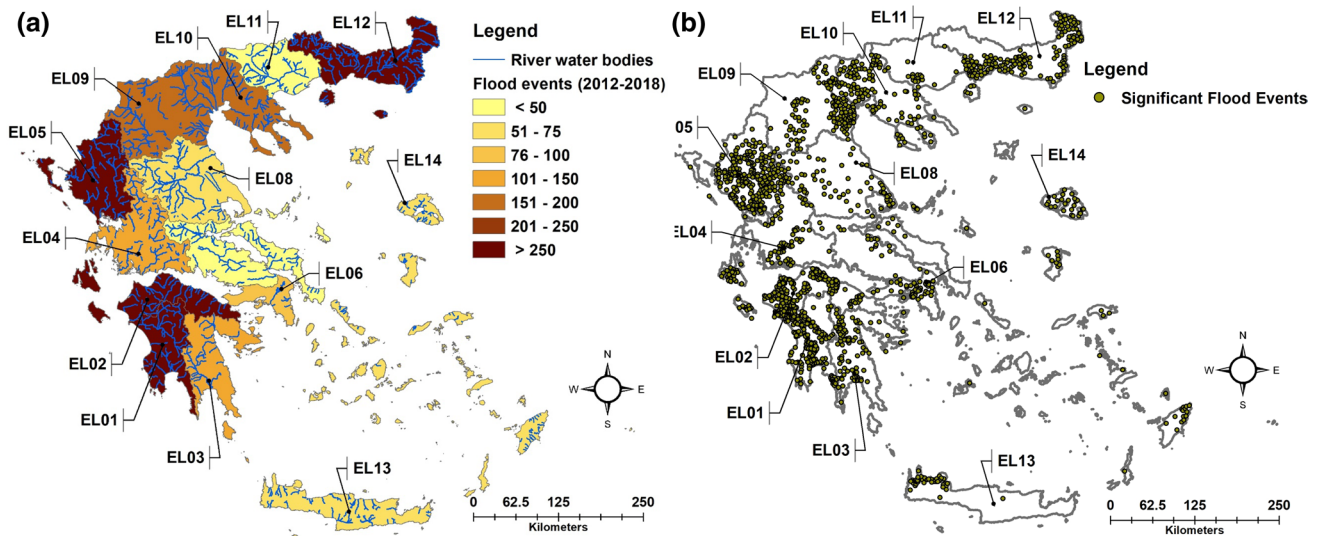


**Fig. 2** Pie charts presentation of the Greek: (a) RWBs' chemical status with blue, orange, and grey colors representing "good", "failing to achieve good", and "unknown" RWBs status, respectively; and (b)

RWBs' ecological status with dark blue, blue, green, orange, red, and grey colors attributing the "high", "good", "moderate", "poor", "bad", and "unknown" status of the river water bodies, respectively

preliminary linkage of the RWBs' name with potential quality, i.e. WFD, of quantity (flood), i.e. FD, problems is given in the last column of Table 2. However, within the research all the 134 selected RWBs are investigated for their connection with both the WFD and FD implementation process outputs.

The selected 134 RWBs with characteristic toponyms are located either in a single RBD or in multiple RBDs. For example, the water bodies named as "Reversed river" are found solely in the RBD of Crete (EL13) while those named as "Black river" are within the EL01, EL07, EL09, EL10, EL11, and EL12 River Basin Districts. Synoptically, 5 RWBs belong to the RBD of Western Peloponnese (EL01),



**Fig. 3** **a** Colored classification of the significant floods per RBD with light yellow and dark orange polygons representing less than 50 and more than 250 events, respectively, for the period 2012–2018, and **b** locations of the significant flood events occurrence during the period 2012–2018

1 RWB belong to the RBD of Northern Peloponnese (EL02), 3 RWBs are in the RBD of Eastern Peloponnese (EL03), 2 RWBs are in the RBD of Western Central Greece (EL04), 1 RWB is in the RBD of Epirus (EL05), 9 RWBs belong to the RBD of Eastern Central Greece (EL07), 5 RWBs belong to the RBD of Thessaly (EL08), 18 RWBs are in the WBD of Western Macedonia (EL09), 10 RWBs are found both in the RBD of Central Macedonia (EL10) and the RBD of Eastern Macedonia (EL11), 38 RWBs are in the RBD of Thrace (EL12), 26 RWBs are in the RBD of Crete (EL13), 6 RWBs are in the RBD of the Aegean Islands (EL14), while none RWB with characteristic toponyms was found in the RBD of Attica (EL06).

## Results

### RWBs classification

Within the 2nd cycle of the development of the RBMPs by the EU's Member-States, a new generic typology for European rivers is adopted for homogenization and comparison purposes. This new broad typology reflects the natural variability in the most commonly used environmental type descriptors, such as the altitude, geology, and size (Solheim et al. 2019). Denoted as RW-XX, 21 different types have been created, i.e. varying from RW-00 to RW-20. Apart from RW-00 that corresponds to lack of data and RW-01 that indicates very large rivers, all the other descriptors attribute the characteristics of the river water body. In the research, the

river water bodies are identified and classified accordingly to provide a clear overview of the water bodies' typologies.

Based on the aforementioned typology classification, 0.61% of the Greek RWBs are not assigned to a specific category and they belong to the category RW-00, 1.97% or 26 RWBs are attributed as very large rivers (RW-01), 10.63% of the RWBS belong to the category RW-10 -Highland or glacial, 32.12% (423 RWBs) are characterized as Mediterranean, perennial, medium or large, i.e. category RW-10, and 54.67% (720 RWBs) of the RWBs belong to the RW-12 type, i.e. they are Mediterranean, temporary or small water bodies. As it is presented in the typology distribution per RBD of Fig. 4, all the RWBs of the EL14, i.e. the RBD of the Aegean Islands, are typical Mediterranean rivers with ephemeral flow (RW-12), while the RWBs characterized as very large rivers (RW-01) are those belonging in EL09, EL10, EL11, EL12 River Basin Districts and form part of the transboundary rivers of Greece (Skoulikaris 2021).

Focused on the selected RWBs with characteristic toponyms, 15 RWBs or 11.2% are categorized as "RW-10 – Highland or glacial", 27 RWBs or 20.1% are classified as "RW-11 – Mediterranean, perennial, medium or large", and 92 water bodies or 68.7%, are classified as "RW-12 – Mediterranean, temporary or small". These figures are in compliance with the current literature demonstrating that intermittent rivers and ephemeral streams are dominant in the Mediterranean river networks (Stubington et al. 2018). Especially, the flow is perennial only in sections where channels intersect with aquifers while in cases that the channels are hydraulically disconnected from aquifers the flow is intermittent, but surface water is still present in form of isolated pools (Camarasa-Belmonte 2016). On the other hand,

**Table 2** List of the Greek RWBs whose characteristic toponyms indicate potential implications with the WFD and/or FD implementation processes

RWBs in Greek	RWBs in English	No of RWBs	Selected RWBs justification based on their toponyms	Expected linkage with:
<i>Αλιμροπόταμος, Αλιμρός</i>	Salty rivers	6	RWBs are in islands and are fed by groundwater sources with salty water (Kotti et al. 2018)	Water quality
<i>Αναποδάριης</i>	Reversed river	15	Due to sea water penetration into the river caused by frequent winds, the river seems to flow towards the opposite direction (Kritsotakis and Tsanis 2009)	Water quality and coastal floods
<i>Αράπις, Αραπίτσα</i>	"Arabs" rivers	5	The name is attributed to the black color of the river due to the dense vegetation within the river and in its riverside	Water quality
<i>Αρκουδόρεμα</i>	Bears' stream	8	No mankind innervations, thus a suitable location for bears (Mertzanis 1994; Skoulidakis et al. 2022)	Water quality
<i>Ασπροπόταμος, Ασπρος, Ασπρόπετρα, Ασπρόρεμα</i>	White rivers	7	The name is attributed to the white colour of turbulent waters during floods	Floods
<i>Γοργοπόταμος</i>	Speedy rivers	2	The name is related to the acceleration of the waters due to the high slope of the riverbed	Floods
<i>Διαβολόρεμα</i>	Devil's stream	9	The vegetation on the steep terrain is very dense as well as the runoff is rapidly accelerated during precipitation events, thus it is considered a suitable location for the devil's settlement	Water quality and floods
<i>Λασπίας</i>	Muddy river	2	The river takes its name due the sediment transfer during floods as well its role as a drainage channel (Gikas 2017)	Water quality and floods
<i>Μαυρόρεμα, Μαύρουερι, Μαυροπόταμος, Μαυροζούμεια, Μαυρομύτης, Μέλας ποταμός</i>	Black rivers	24	The name is attributed to the black color of the rivers due to the dense vegetation within their riverbed and in their riverside	Water quality
<i>Μελισσόρεμα, Μελισσαχωρίου ρέμα</i>	Bees' rivers	6	The name is related to the good fauna conditions for bee breeding	Water quality
<i>Ξεριάς, Ξηροπόταμος, Ξηρόλαγκας, Ξηρόρεμα, Ξηρόρεμα</i>	Dry rivers	37	Typical ephemeral rivers that have increased flows during high precipitation events	Water quality and floods
<i>Ταυρουίτης</i>	Bull's rivers	6	The loss of bulls grazing near the river due to flood events is the reason of the RWB name	Floods
<i>Τσικιιάς</i>	Great Erget's rivers	3	The name is attributed to the large population of Great Ergets birds coming to this area during the migration period (Nabih et al. 2021)	Water quality
<i>Φουιάς, Φούισσα ρέμα</i>	Murder's rivers	4	Due to its steep slopes, the water is rapidly accelerated during precipitation events resulting in various human losses (Skoulikidis et al. 2020)	Floods

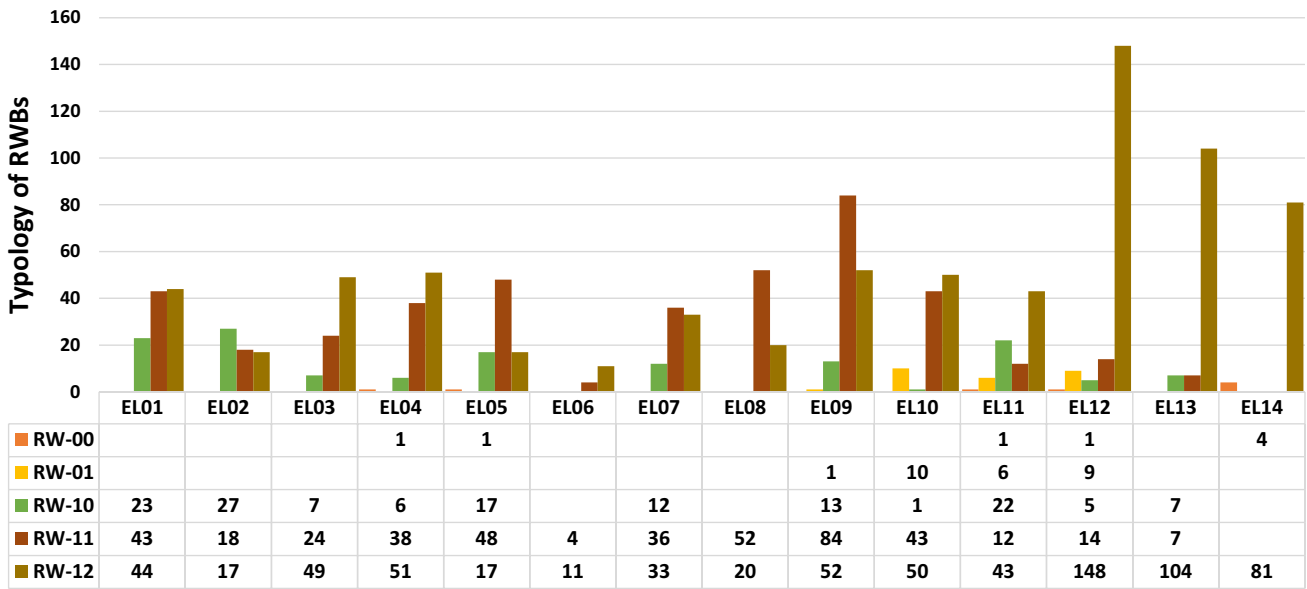


Fig. 4 Classification typology of the Greek RWBs to perennial, temporal, small, large type of RWBs

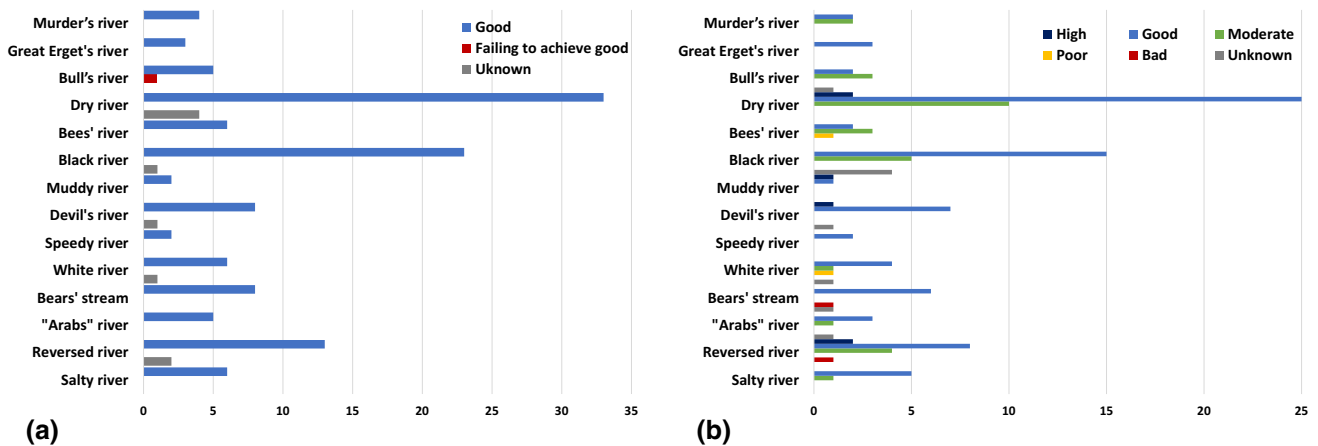


Fig. 5 Quality status of the RWBs with characteristic toponyms demonstrated in form of clustered bars for: **a** the chemical status of the RWBs, and **b** the ecological status of the RWBs

the ephemeral rivers form dry stream beds during the dry-period condition as the water disappears (Argyroudi et al. 2009). The fact that in the case study area 37 distinct RWBs are named as "Dry rivers" clearly indicates the existence of ephemeral rivers.

**RWBs quality characteristics**

The analysis of the quality characteristics of the selected RWBs revealed that 92.5%, i.e. 124 out of 134 RWBs, have good chemical status, 1 RWB fails to achieve good status, while the chemical status of 9 RWBs, i.e. for 6.7% of the RWBs, is unknown. Regarding the ecological status, 5 and

85 RWBs have high and good ecological status, respectively, representing 3.7% and 63.4% of the selected RWBs, respectively, while the ecological status of 31 RWBs or 23.1% is moderate. The ecological status is poor and bad for 2 RWBs, respectively, while the status of 9 RWBs or 6.7% is unknown. The distribution of the chemical and ecological status per water body toponym class is depicted in Fig. 5a and b, respectively.

All the water bodies whose toponym implies a good water quality (see Table 2), such as the Great Erget's river, Bees' rivers, Devil's rivers, and the Bears' stream (26 water bodies in total), are proved to have a good chemical status, Fig. 5a. Moreover, 73% of these 26 water bodies have high or good



ecological status, 12% have a moderate one while there are only 2 water bodies who have poor or bad ecological status, Fig. 5b. The rest water bodies with characteristic toponyms whose name suggests a connection with the water quality (89 in total), e.g. the Dry rivers, the Black rivers, the Muddy rivers, the Arabs' rivers, the Reversed rivers and the Salty rivers, (see Table 2), also demonstrate an impressive good chemical status with 82 out of 89 having a good chemical status and 7 having an unknown one, Fig. 5a. In terms of ecological status, 70% of these 89 water bodies have high or good ecological status, 24% are classified with moderate ecological status and only 2 water bodies have either poor or bad ecological status, Fig. 5b.

Focusing on the ecological status as the one that presents the larger variations, all the RWBs that are characterized with high and good ecological status, i.e. 90 in total, and in accordance to the type of pressures classification of the WFD (EC 2003c), are not connected to mankind activities and are classified in the category "P0 – No significant anthropogenic pressure". On the other hand, 10 RWBs are classified within the category "P1 – Point sources", since point sources pressures have been identified, 19 RWBs are connected with the category "P2 – Diffuse sources" with agricultural pressures to have been observed, 4 RWBs are classified as "P3 – Abstraction" since pressures related to abstractions for covering the irrigated demands on water have been recorded. Moreover, 3 RWBs are linked with pressures related to the hydrological alterations of the channel/bed/riparian area/shore for public water supply or for flood protection or for irrigation purposes and are categorized as having "P4 – Hydromorphology" pressures. Finally, 1 RWB is connected with pressures related with animal breeding and belongs to the category "P5 – Introduced species and litter", while for 7 RWBs the pressures are anthropogenic but not defined, thus they belong to the category "P8 – Anthropogenic pressure – Unknown".

### RWBs' connection with floods

The cross-correlation between the selected RWBs and the significant flood events at national scale for the period 2012–2018 was conducted with the use of spatial analysis under geographic information system environment. Based on a proximity criterion of selecting the floods that intersect or/and are within a distance less than 200 m from the RWBs with characteristic toponyms, it was found out that 102 significant floods, i.e. 5.22% of the national significant floods, were occurred within or in a close distance of these RWBs. According to the floods impact classification of the FD (EC 2020), 49% of the floods (50 out of 102 events) are classified as having economic impacts on properties, i.e. they belong to the impacts' category "B41 – Property", and 51% of the events as having economic impacts on infrastructures, i.e.

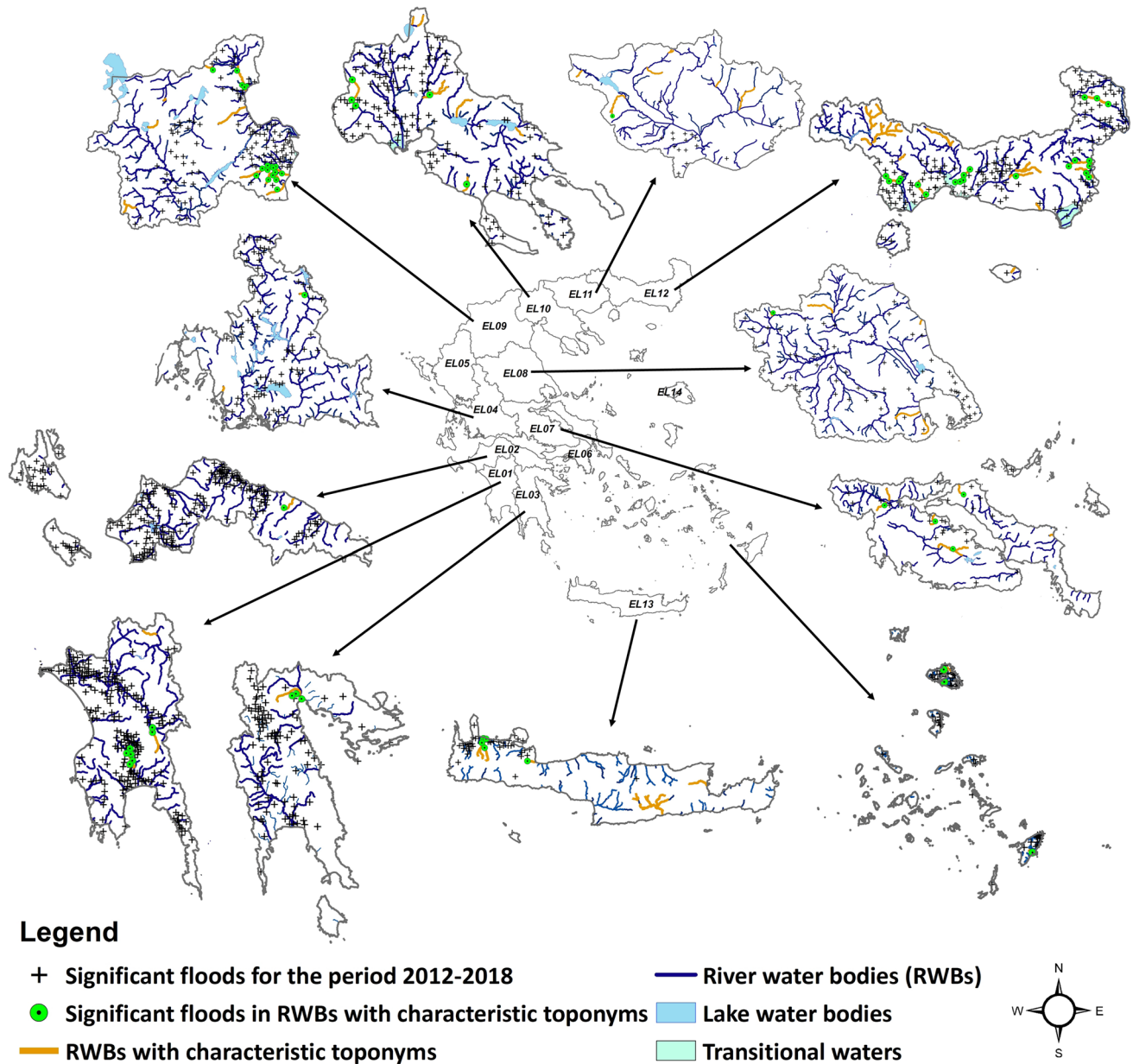
they belong to the impacts' category "B42 – Infrastructure". At the same time, 36 significant floods apart from the economic impacts they did also have impacts on the rural environment, i.e. they also belong to the category "B43 – Rural land use". What is worth mentioning, is that none of the 102 recorded significant floods within or close to the RWBs with characteristic toponyms is linked to human fatalities during the case study period.

Focusing on each RBD, 7 significant floods are related to the RWBs with characteristic toponyms in the River Basin District EL01, 1 flood occurred in the selected RWBs of the RBDs EL02, EL04 and EL11, respectively, 3 significant floods took place in the RWBs with characteristic toponyms of the RBDs EL03, EL08 and EL14, respectively, 6 events appeared in the RWBs of EL07, and 5 events are connected with the RWBs of EL13. The most floods, i.e. 41 flood events, occurred on the RWBs with characteristic toponyms of the RBD EL12, followed by 19 and 12 floods occurred on the RWBs of the RBDs EL09 and EL10, respectively. An overall illustration of the significant flood events per RBD together with the 134 RWBs with characteristic toponyms is presented in Fig. 6.

In terms of the RWBs with characteristic toponyms that imply flood prone areas (82 RWBs in total, see Table 2), e.g. the Reversed river, the White rivers, the Speedy rivers, the Muddy rivers, the Dry rivers, the Devil's stream, the Bull's rivers and the Murder's rivers, the data analysis confirmed that 67 significant floods, i.e. ~66% of the floods under investigation, are related with the specific RWBs. Particularly, 34 significant floods occurred within or close to the Dry rivers, 12 floods conducted in Devil's steam, 10 significant floods were recorded within or close to the White rivers, 4 significant floods were mapped within the Bulls and Muddy rivers, respectively, 2 floods occurred in the Murder's river, 1 flood took place in the Speedy river, while no significant flood has been recorded in the Reversed river. It is worth mentioning that the rest 35 flood events took place on the RWBs whose toponym is mainly related to the water quality and not with floods. Especially, 32 significant flood events have been recorded in the Black rivers during the time period 2012–2018. For consistency purpose, and in order to demonstrate the lack of thorough information before the development and operation of the floods' database in 2012, the figures of the significant floods per RWBs with characteristic toponym for the reference period as well as until the year 2011 are given in Fig. 7.

## Discussion

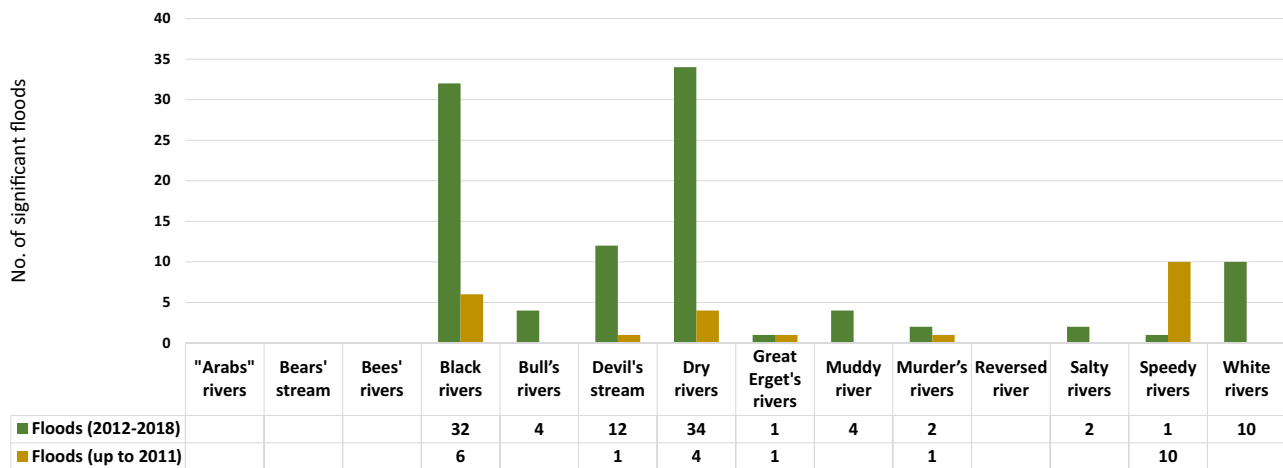
In the research, qualitative characteristics of the river water bodies, such as their toponyms, are proposed as proxies for the facilitation of the WFD and FD implementation process.



**Fig. 6** Presentation of the significant floods and their spatial relation with the river water bodies with characteristic toponyms for all the RBDs of Greece

Both Directives are driving forces to applied science, with serious amount of dedicated researches on the various processes included in the Directives to be presented in the literature. In particular, several proxy data-methods have been used or suggested for the implementation of the Directives, e.g. simplified ecotoxicological approaches for prioritization of the most critical areas impacted by deactivated mines (Vidal et al. 2012), or use of diatoms to assess the ecological status of phytobenthos in lakes (Kelly et al. 2008), or the replacement of the morphological identification used in the ecological status assessment by procedures using eDNA

(Hering et al. 2018), or earth observation (EO) data from Landsat 7 Enhanced Thematic Mapper Plus and Landsat 8 Operational Land Imager sensors for lake quality assessment when ground truth data is limited (Markogianni et al. 2022) or application of the "indicator of intense pluvial runoff" geomatics method that allows mapping the susceptibility of a territory to surface runoff (Braud et al. 2020) or use of dendrogeomorphologically well-defined recorded flood events for the calibration and validation of the hydraulic models for the simulation of flood hazards (Ballesteros-Cánovas et al. 2013). However, the use of river water bodies' toponyms as a



**Fig. 7** Distribution of recorded significant floods per RWB with characteristic toponym at the national scale of Greece for the periods 2012–2018 and until the year 2011

knowledge index of the rivers water quality and of the flood prone areas investigated in the WFD and FD, respectively, is rather limited and is considered the innovation of the current research.

In terms of water bodies' quality, it is demonstrated that the 134 RWBs with characteristic toponyms have slightly better chemical status in comparison to the RWBs' status at a Greek national level. Particularly, 92.5% of the RWBs under investigation have good chemical status, while at national level 89.2% of the RWBs are attributed with good chemical status. Focusing on the ecological status, almost half, i.e. 5 out of 11, of the water bodies that are characterized with high ecological status at national scale are among the selected RWBs. Moreover, the ones with good ecological status represent 63.4% of the RWBs with characteristic toponyms instead of the 62.4% at national level. Similarly, the status of 23.1% of the selected RWBs is moderate compared to the 22.7% at a national level. Finally, the chemical status is unknown only for 6.7% of the selected RWBs in comparison to the 8.9% at national level. It should be mentioned that the identification of water bodies is primarily based on geographical and hydrological determinants (EC 2003a). Areas of increased number of river confluences, due to the topography characteristics, result on demarcating numerous distinct water bodies' boundaries and hence posing an augmented administrative and technical burden for the water bodies' monitoring. Bulgaria's river basins neighboring Greece is a characteristic example of the mismatch between increased number of water bodies and monitoring capabilities, since the chemical status of 75.3% of the Bulgarian water bodies is unknown (Skoulikaris 2021). Consequently, the use of proxy methodologies, such as the one proposed in the research, could facilitate the monitoring priorities in areas where the lack of monitoring stations is dominant.

Regarding the river water bodies whose toponym lectically suggests flood prone areas, i.e. 82 RWBs, the research depicts that 67% of the significant floods under investigation during the period 2012–2018 are related to the specific RWBs. The fact that these 82 RWBs represent 61% of the 134 RWBs with characteristic toponyms evaluated in the research, establishes a solid connection in terms of river toponyms and flood occurrence. Moreover, 81.7% (67 out of 82 RWBs) of the RWBs with toponyms that imply floods are categorized as "RW-11 – Mediterranean, perennial, medium or large" and "RW-12 – Mediterranean, temporary or small" (see "RWBs classification" section, i.e. they are typical fluvial systems of Mediterranean and semi-arid zones having high risk of flash flooding mainly due to the watershed small size, the intensity of precipitation and the soil conditions (Kastridis et al. 2020; Schoener and Stone 2019; Llasat et al. 2010; Bracken et al. 2008)). Even currently, these hydrographic systems are poorly understood because of the technical difficulties in gauging ephemeral stream channels and the low economic interest in these fluvial systems (Camarasa-Belmonte 2016). Hence, the proposed water bodies' toponym methodology concept can be an auxiliary approach for selecting those flood "generator" streams that need to be further investigated during the FD implementation process.

At the same time, Hrdinka et al. (2012) suggested that flood events might have significantly greater impact on the water quality than drought events, mainly due to extreme concentrations of suspended solids originating predominantly from vast alluvial washouts. Although several well-defined water quality models exist and have been applied to large hydrosystems, their applicability to small rivers and especially to intermittent and ephemeral ones is doubtfully due to lack of monitoring data for models' validation

as well as the unique features of small rivers, such as shallow water depths or intense flow turbulence during storm events, which largely differ from those of larger riparian systems (Mannina and Viviani 2010). The WFD also does not specifically differentiate its implementation processes between perennial and intermittent or ephemeral streams (Fritz et al. 2017). Research on the water quality of various intermittent rivers in Greece, e.g. on the Vosvozis River in the RBD EL12 (Boskidis et al. 2010) or the Evrotas River in the RBD EL03 (Karaouzas et al. 2018), show that the pollution in these systems may be severe during drought periods. On the contrary, the current research validates that the water quality of the 134 RWBs with characteristic toponyms, of which 119 RWBs are of RW-11 and RW-12 types (~ 90.0%), is good, since more than 90% and 85% of these water bodies have good chemical and at least moderate ecological status, respectively; consequently, hydronyms can offer increased information about the quality status of streams/rivers that are missing monitoring infrastructure.

It should be noted that in case of non-stationary data, such as those of flood peak flows, the recent literature (Hesarkazzazi et al. 2021) demonstrates that the non-stationarity should be properly elaborated in the various simulation processes. However, the research focuses only on the number of monitored flood events of the period 2012–2018, thus the stationarity or not of the data is not considered. The per year analysis of the recorded significant floods demonstrated a large variation between the recorded flood events, e.g. 312 floods in 2012 versus 177 floods of 2014 and versus the 235 floods of 2015. In general, a small increasing trend of the significant floods is presented through the case study period at national level. This increasing trend, nevertheless, is not prevailing in each of the 14 Greek RBDs. A characteristic example is the RBD of Northern Peloponnese (EL02), where the 128 observed significant floods of 2012 are much higher than the 10 floods of 2018. Moreover, although flood frequency and intensity is expected to increase in forthcoming years at global scale (Douville et al. 2021), it should be taken into consideration that developed countries, such as those of the EU, are implementing flood protection and management policies, e.g. the Floods Directive, where significant funds are invested in flood protection measures and structures for floods mitigation.

The 7-years reference time period, i.e. from 2012–2018, is rather a limitation of the research, since longer time series of flood events occurrences could establish more secure outputs. Towards this direction, the updated version of the floods database that will be launched at the finalization of the 2nd cycle of the FRMPs in 2024 and will be populated with flood events of a 13-years period (2012–2014), is conceived as the future development of the current research. In parallel, the investigation of the impacts of the human

development on rural areas and the induced alteration on land uses with the use of terrain toponyms combined with the regional hydronyms is also proposed as an advanced thematic for research and is planned to be applied soon.

To sum up, the EU Water Framework and Floods Directives are fundamental instruments towards the water resources and floods management, respectively, with the water bodies designated as the kernel of the Directives' implementation processes as well as the link between them. Nevertheless, flow-dependent monitoring frameworks should be further developed and implemented in the future to verify the connection between floods and water quality (St-Hilaire et al. 2016). In the Mediterranean countries, which few of them are in EU, and where intermittent rivers and ephemeral streams prevail, solutions for the monitoring and mapping the spatio-temporal variability of flow regimes and their influence on the waters' bio-physical variables is necessitated (Borg Galea et al. 2019). The research indicates that the water bodies' toponyms can offer empirical knowledge both on their quality status and the floods occurrence, therefore providing background information for further investigation in areas with negligible observation data. In large ungauged areas, for example, the selection of the water bodies (or streams) where monitoring stations should be installed, or the selection of those water bodies (or streams) that need to be hydraulically simulated can be facilitated by the use of the proposed methodology. Concluding, the research is applied at an EU Member-State, however in can be easily transferred at any other country where inventories of historic floods are available.

## Conclusions

The importance of the paper derives from its conceptual approach to investigate the way that proxy data, i.e. the names of the water bodies, can facilitate the Water Framework and Flood Directives implementation process. The research highlights that the background knowledge hidden within the hydronyms of the water bodies is a neglected asset which in most cases depicts the quality of the waters and/or the susceptibility of the water bodies in flood events.

At water bodies quality level, which is attributed as a combination of their chemical and ecological status, the water bodies with toponyms that imply good quality status is proved to indeed have good chemical status (100% of the specific RWBs) and 85% of them to have at least moderate ecological status. Moreover, the RWBs whose toponym indicate an ambiguous connection with the water quality in terms of their good or bad status, e.g. the Dry rivers, are shown to also have good chemical (> 92% of the specific RWBs) and ecological (> 70% of the RWBs) status. In terms of RWBs whose toponyms suggest flood prone areas, it is

revealed that ~66% of the significant floods under investigation during the period 2012–2018 are related with the specific RWBs. Finally, the RWBs with characteristic toponyms proved to largely be intermittent and ephemeral water bodies, i.e. water segments that cannot be easily monitored and thus accurately simulated. The latter together with the fact that in many EU Member States there is an important percentage of water bodies with unknown quality status renders the proposed methodological concept an important roadmap for the preliminary assessment of the water quality and induced floods of water bodies with characteristic toponyms.

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## Declarations

**Conflict of interest** There is no conflict of interest.

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## References

- Argyroudi A, Chatzinikolaou Y, Poirazidis K, Lazaridou M (2009) Do intermittent and ephemeral Mediterranean rivers belong to the same river type? *Aquat Ecol* 43(2):465–476. <https://doi.org/10.1007/s10452-008-9176-9>
- Ballesteros-Cánovas JA, Sanchez-Silva M, BodoqueDíez-Herrero JMA (2013) An integrated approach to flood risk management: a case study of Navaluenga (Central Spain). *Water Resour Manag* 27(8):3051–3069. <https://doi.org/10.1007/s11269-013-0332-1>
- Borg Galea A, Sadler JP, Hannah DM, Detry T, Dugdale SJ (2019) Mediterranean intermittent rivers and ephemeral streams: challenges in monitoring complexity. *Ecology* 12(8):e2149. <https://doi.org/10.1002/eco.2149>
- Boskidis I, Gikas GD, Pisinaras V, Tsihrintzis VA (2010) Spatial and temporal changes of water quality, and SWAT modeling of Vosvovis river basin, North Greece. *J Environ Sci Health A* 45(11):1421–1440. <https://doi.org/10.1080/10934529.2010.500936>
- Bracken LJ, Cox NJ, Shannon J (2008) The relationship between rainfall inputs and flood generation in south-east Spain. *Hydrol Process* 22(5):683–696. <https://doi.org/10.1002/hyp.664>
- Braud I, Lagadec LR, Moulin L, Chazelle B, Breil P (2020) A method to use proxy data of runoff-related impacts for the evaluation of a model mapping intense storm runoff hazard: application to the railway context. *Nat Hazards Earth Syst Sci* 20(4):947–966. <https://doi.org/10.5194/nhess-20-947-2020>
- Brillinger M, Dehnhardt A, Schwarze R, Albert C (2020) Exploring the uptake of nature-based measures in flood risk management: evidence from German federal states. *Environ Sci Policy* 110:14–23. <https://doi.org/10.1016/j.envsci.2020.05.008>
- Bubeck P, Aerts JCJH, de Moel H, Kreibich H (2016) Preface: flood-risk analysis and integrated management. *Nat Hazards Earth Syst Sci* 16:1005–1010. <https://doi.org/10.5194/nhess-16-1005-2016>
- Camarasa-Belmonte AM (2016) Flash floods in Mediterranean ephemeral streams in Valencia region (Spain). *H Hydrol* 541:99–115. <https://doi.org/10.1016/j.jhydrol.2016.03.019>
- Carvalho L, Mackay EB, Cardoso AC et al (2019) Protecting and restoring Europe's waters: an analysis of the future development needs of the water framework directive. *Sci Total Environ* 658:1228–1238. <https://doi.org/10.1016/j.scitotenv.2018.12.255>
- De Vito L, Fairbrother M, Russel D (2020) Implementing the water framework directive and tackling diffuse pollution from agriculture: lessons from England and Scotland. *Water* 12(1):244. <https://doi.org/10.3390/w12010244>
- Douville H et al (2021) Water Cycle changes climate change 2021: The physical science basis. In: Masson Delmotte V et al (ed) Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, London, UK, pp 1055–1210.
- EC (2000) Directive 2000/60/EC of the European parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (water framework directive). *Off J Eur Communities* L327 1–72, 22 December.
- EC (2003a) Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance Document No 2: Identification of Water Bodies, Working Group on Water Bodies. European Communities publication, Luxembourg.
- EC (2003b) Common implementation strategy for the water framework directive (2000/60/EC). Guidance Document No 7: Monitoring under the Water Framework Directive, Working Group 2.7 – Monitoring. European Communities publication, Luxembourg.
- EC (2003c) Common implementation strategy for the water framework directive (2000/60/EC). Guidance Document No 3: Analysis of Pressures and Impacts, Working Group 2.1 – IMPRESS. European Communities publication, Luxembourg.
- EC (2007) Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks. *Off J Eur Communities* L288 27–34, 6 November.
- EC (2008) Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council. *Off J Eur Communities* L348 84–97, 24 December.
- EC (2013) Directive 2013/39/EU of the European parliament and of the council of 12 August 2013 amending directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy. *Off J Eur Communities* L226 1–17, 24 August.
- EC (2020) Floods Directive GIS Guidance. Guidance on the reporting of spatial data to the Water Information System for Europe. Version 7.0.3. 2020–01–07. Directorate-General for the Environment, European Commission. [https://cdr.eionet.europa.eu/help/Floods/Floods\\_2018/GuidanceDocuments/Floods\\_GISGuidance.pdf](https://cdr.eionet.europa.eu/help/Floods/Floods_2018/GuidanceDocuments/Floods_GISGuidance.pdf). Accessed: 11 April 2022.
- EC (2021) European Overview - Implementation of planned Programmes of Measures and New Priority Substances. Commission staff working document SWD(2021) 970 final. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021SC0970>. Accessed: 18 April 2022.
- EEA (2018) European waters-assessment of status and pressures. EEA Report I No 7/2018. ISSN 1977–8449.

- Ergönül MB, Breine J, Van den Bergh E (2018) A technical guide to develop a statistically valid fish-based index in compliance with the water framework directive: an evaluation for Turkish freshwaters. *Int Aquat Res* 10(4):303–319
- Frajer J, Fiedor D (2018) Discovering extinct water bodies in the landscape of Central Europe using toponymic GIS. *Morav Geogr Rep* 26(2):121–134. <https://doi.org/10.2478/mgr-2018-0010>
- Fritz K, Cid N, Autrey B (2017) Governance, legislation, and protection of intermittent rivers and ephemeral streams. In: Detry T, Bonada N, Boulton A (eds) *intermittent rivers and ephemeral streams*. Elsevier, Amsterdam, The Netherlands, pp 477–507
- Gikas GD (2017) Water quantity and hydrochemical quality monitoring of Laspis River, North Greece. *J Environ Sci Health A* 52(14):1312–1321. <https://doi.org/10.1080/10934529.2017.1357408>
- Goytia S (2021) Issues of natural resources law for adopting catchment-based measures for flood risk management in Sweden. *Sustainability* 13(4):2072. <https://doi.org/10.3390/su13042072>
- Hartmann T, Driessen P (2017) The flood risk management plan: towards spatial water governance. *J Flood Risk Manag* 10(2):145–154. <https://doi.org/10.1111/jfr3.12077>
- Hartmann T, Spit T (2016) Implementing the European flood risk management plan. *J Environ Plan Manag* 59(2):360–377. <https://doi.org/10.1080/09640568.2015.1012581>
- Heintz MD, Hagemeyer-Klose M, Wagner K (2012) Towards a risk governance culture in flood policy—findings from the implementation of the “floods directive” in Germany. *Water* 4(1):135–156. <https://doi.org/10.3390/w4010135>
- Hellenic Ministry of Environment and Energy (2019). 1<sup>st</sup> Revision of the Preliminary Flood Risk Assessment and Areas of Potential Significant Flood Risk. [https://cdr.eionet.europa.eu/gr/ef/floods2019/pfra\\_2019/documents/national/envx7ufyg/PFRA\\_REVISIION\\_REPORT\\_vf.pdf](https://cdr.eionet.europa.eu/gr/ef/floods2019/pfra_2019/documents/national/envx7ufyg/PFRA_REVISIION_REPORT_vf.pdf) (In Greek). Assessed 3 May 2022.
- Hering D, Borja A, Jones JI et al (2018) Implementation options for DNA-based identification into ecological status assessment under the European water framework directive. *Water Res* 138:192–205. <https://doi.org/10.1016/j.watres.2018.03.003>
- Hesarkazzazi S, Arabzadeh R, Hajibabaei M, Rauch W, Kjeldsen TR et al (2021) Stationary vs non-stationary modelling of flood frequency distribution across northwest England. *Hydrol Sci J* 66(4):729–744. <https://doi.org/10.1080/02626667.2021.1884685>
- Hrdinka T, Novický O, Hanslík E, Rieder M (2012) Possible impacts of floods and droughts on water quality. *J Hydro-Environ Res* 6(2):145–150. <https://doi.org/10.1016/j.jher.2012.01.008>
- Jager NW, Challies E, Kochskämper E et al (2016) Transforming European water governance? Participation and river basin management under the EU water framework directive in 13 member states. *Water* 8:156. <https://doi.org/10.3390/w8040156>
- Karouzias I, Theodoropoulos C, Vardakas L et al (2018) A review of the effects of pollution and water scarcity on the stream biota of an intermittent Mediterranean basin. *River Res Appl* 34(4):291–299. <https://doi.org/10.1002/rra.3254>
- Kastridis A, Kirkenidis C, Sapountzis M (2020) An integrated approach of flash flood analysis in ungauged Mediterranean watersheds using post-flood surveys and unmanned aerial vehicles. *Hydrol Process* 34(25):4920–4939. <https://doi.org/10.1002/hyp.13913>
- Kelly MG, King L, Jones RI et al (2008) Validation of diatoms as proxies for phytoplankton when assessing ecological status in lakes. *Hydrobiologia* 610(1):125–129. <https://doi.org/10.1007/s10750-008-9427-8>
- Kharusi NS, Salman A (2015) In search of water: hydrological terms in Oman’s toponyms. *Names* 63(1):16–29. <https://doi.org/10.1179/0027773814Z.000000000094>
- Kotti M, Zacharioudaki DE, Kokinou E et al (2018) Characterization of water quality of Almiros river (Northeastern Crete, Greece): physicochemical parameters, polycyclic aromatic hydrocarbons and anionic detergents. *Model Earth Syst Environ* 4:1285–1296. <https://doi.org/10.1007/s40808-018-0504-3>
- Kritsotakis M, Tsanis IK (2009) An integrated approach for sustainable water resources management of Messara basin, Crete Greece. *Eur Water* 27(28):15–30
- Llasat MC, Llasat-Botija M, Prat MA et al (2010) High-impact floods and flash floods in Mediterranean countries: the FLASH preliminary database. *Adv Geosci* 23:47–55. <https://doi.org/10.5194/adgeo-23-47-2010>
- Luo W, Hartmann JF, Wang F (2010) Terrain characteristics and Tai toponyms: a GIS analysis of Muang Chiang and Viang. *Geojournal* 75(1):93–104. <https://doi.org/10.1007/s10708-009-9291-8>
- Maia R (2017) The WFD implementation in the European member states. *Water Resour Manag* 31(10):3043–3060. <https://doi.org/10.1007/s11269-017-1723-5>
- Mannina G, Viviani G (2010) Water quality modelling for ephemeral rivers: Model development and parameter assessment. *J Hydrol* 393(3–4):186–196. <https://doi.org/10.1016/j.jhydrol.2010.08.015>
- Markogianni V, Kalivas D, Petropoulos GP, Dimitriou E (2022) Modelling of Greek lakes water quality using earth observation in the framework of the water framework directive (WFD). *Remote Sens* 14(3):739. <https://doi.org/10.3390/rs14030739>
- Mertzanis GA (1994) Brown bear in Greece: distribution, present status: ecology of a northern pindus subpopulation. *Bears: Their Biol Manag*. <https://doi.org/10.2307/3872701>
- Nabih S, Tzoraki O, Zanis P et al (2021) Alteration of the ecohydrological status of the intermittent flow rivers and ephemeral streams due to the climate change impact (case study: Tsiknias river). *Hydrology* 8:43. <https://doi.org/10.3390/hydrology8010043>
- Nones M (2015) Implementation of the floods directive in selected EU member states. *Water Environ J* 29(3):412–418. <https://doi.org/10.1111/wej.12129>
- Nones M (2019) Dealing with sediment transport in flood risk management. *Acta Geophys* 67:677–685. <https://doi.org/10.1007/s11600-019-00273-7>
- Parés M, Brugué Q, Espluga J et al (2015) The strengths and weaknesses of deliberation on river basin management planning: analysing the water framework directive implementation in Catalonia (Spain). *Environ Policy Gov* 25(2):97–110. <https://doi.org/10.1002/eet.1662>
- Ruiz-Villaverde A, García-Rubio MA (2017) Public participation in European water management: from theory to practice. *Water Resour Manag* 31:2479–2495. <https://doi.org/10.1007/s11269-016-1355-1>
- Sah RK, Kumar DN, Das AK (2022) Channel evolution of the Himalayan tributaries in northern Brahmaputra plain in recent centuries. *Acta Geophys* 70:1317–1330. <https://doi.org/10.1007/s11600-022-00780-0>
- Schoener G, Stone MC (2019) Impact of antecedent soil moisture on runoff from a semiarid catchment. *J Hydrol* 569:627–636. <https://doi.org/10.1016/j.jhydrol.2018.12.025>
- Skoulikaris C (2021) Transboundary cooperation through water related EU Directives’ implementation process. The case of shared waters between Bulgaria and Greece. *Water Resour Manag* 35(14):4977–4993. <https://doi.org/10.1007/s11269-021-02983-4>
- Skoulikaris C, Krestenitis Y (2020) Cloud data scraping for the assessment of outflows from dammed rivers in the EU. A case study in South Eastern Europe. *Sustainability* 12(19):7926. <https://doi.org/10.3390/su12197926>
- Skoulikaris C, Venetsanou P, Lazoglou G et al (2022) Spatio-temporal interpolation and bias correction ordering analysis for hydrological simulations: an assessment on a Mountainous River Basin. *Water* 14(4):660. <https://doi.org/10.3390/w14040660>
- Skoulikidis NT, Lampou A, Laschou S (2020) Unraveling aquatic quality controls of a nearly undisturbed Mediterranean Island

- (Samothraki, Greece). *Water* 12:473. <https://doi.org/10.3390/w12020473>
- Skoulidakis NT, Karaouzas I, Amaxidis Y, Lazaridou M (2021) Impact of EU environmental policy implementation on the quality and status of Greek rivers. *Water* 13(13):1858. <https://doi.org/10.3390/w13131858>
- Solheim AL, Globovnik L, Austnes K et al (2019) A new broad typology for rivers and lakes in Europe: development and application for large-scale environmental assessments. *Sci Total Environ* 697:134043. <https://doi.org/10.1016/j.scitotenv.2019.134043>
- St-Hilaire A, Duchesne S, Rousseau AN (2016) Floods and water quality in Canada: a review of the interactions with urbanization, agriculture and forestry. *Can Water Resour J* 41(1–2):273–287. <https://doi.org/10.1080/07011784.2015.1010181>
- Stubbington R, Chadd R, Cid N et al (2018) Biomonitoring of intermittent rivers and ephemeral streams in Europe: current practice and priorities to enhance ecological status assessments. *Sci Total Environ* 618:1096–1113. <https://doi.org/10.1016/j.scitotenv.2017.09.137>
- Tsakiris G (2014) Flood risk assessment: concepts, modelling, applications. *Nat Hazards Earth Syst Sci* 14(5):1361–1369. <https://doi.org/10.5194/nhess-14-1361-2014>
- Vermeulen J, Whiteoak K, Nicholls G et al (2019) Fitness check evaluation of the Water Framework Directive and the Floods Directive: Final evaluation report. European Commission, Directorate-General for Environment.
- Vidal T, Pereira JL, Abrantes N et al (2012) Ecotoxicological assessment of contaminated river sites as a proxy for the water framework directive: an acid mine drainage case study. *Water Air Soil Pollut* 223(9):6009–6023. <https://doi.org/10.1007/s11270-012-1335-x>
- Vijverberg J, Sibbing FA, Dejen E (2009) Lake Tana: Source of the Blue Nile. In: Dumont HJ (ed) *The Nile. Monographiae Biologicae*, vol 89. Springer, Dordrecht. [https://doi.org/10.1007/978-1-4020-9726-3\\_9](https://doi.org/10.1007/978-1-4020-9726-3_9).
- Voulvoulis N, Arpon KD, Giakoumis T (2017) The EU water framework directive: From great expectations to problems with implementation. *Sci Total Environ* 575:358–366. <https://doi.org/10.1016/j.scitotenv.2016.09.228>
- Zacharias I, Liakou P, Biliani I (2020) A review of the status of surface European waters twenty years after WFD introduction. *Environ Process* 7:1023–1039. <https://doi.org/10.1007/s40710-020-00458-z>
- Zhong A, Wu Y, Nie K, Kang M (2020) Using local toponyms to reconstruct the historical river networks in Hubei Province China ISPRS. *Int J Geo-Inf* 9(5):318. <https://doi.org/10.3390/ijgi9050318>
- Zhou Y, Khu ST, Xi B, Su J, Hao F, Wu J, Huo S (2014) Status and challenges of water pollution problems in China: learning from the European experience. *Environ Earth Sci* 72(4):1243–1254. <https://doi.org/10.1007/s12665-013-3042-3>