A catalogue of European intermittent rivers and ephemeral streams

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SMIRES Science and Management of Intermittent Rivers and Ephemeral Streams

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Summary

SMIRES (Datry *et al.*, 2017) is a COST Action addressing the Science and Management of Intermittent Rivers & Ephemeral Streams (coord. T. Datry, INRAE, and G. Singer, University of Innsbruck; http://www.smires.eu). This COST Action had brought together scientists from various research field and stakeholders to develop a European multidisciplinary network for synthesising the fragmented and recent knowledge on temporary water courses, improving our understanding of Intermittent Rivers and Ephemeral Streams (IRES) and translating this into a science-based, sustainable management of river networks.

The working group "*Prevalence, distribution and trends of IRES*" (WG1) has the central role to provide the physical basis of the SMIRES Action. One of the tasks of WG1 was to compile flow gauging data at the European scale. As part of this work, examples of intermittent rivers and ephemeral streams were collected across Europe, including gauged catchments with both natural and highly influenced river flow regimes. A total of 40 examples have been put together in this catalogue to provide an overview of the variety of IRES in Europe. The selected IRES are not meant to be representative of all intermittent water courses in Europe but rather highlight the variety in these water courses.

Introductory pages describe the procedures used to create the catalogue including definitions of the statistical measures reported for the individual intermittent rivers and ephemeral streams, and provide an overview of the catalogued water courses. Information on the selected gauged intermittent rivers and ephemeral streams is summarised in a two-page document:

- The first standardized page describes the main characteristics of the catchments (land-use, geology, climate, etc.) and the river flow regime. Two panels display the hydrographs and flow durations curves, and a table gives metrics specific to river flow intermittence relevant for ecology.
- The second page is dedicated to the description and reasons for intermittence. A short description about the spatio-temporal pattern of zero-flow events. This section may describe the seasonal behaviour of the stream, observed long-term trends, locations with frequently observed zero-flow events along the river network, etc. The monitoring network, including gauging stations and other types of observations (e.g. visual inspection of the flow states at different locations along the river) in the catchment, are also described.

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1. Introduction

Temporary water courses are water courses that undergo a recurrent cessation of flow or complete drying of the channel (Uys and O'Keefe, 1997). This type of water course is not only widespread in dry climates (e.g. Rossouw *et al*., 2005; Levick *et al*., 2008), but also in the headwaters of many drainage basins in wetter climates (Fritz *et al*., 2006; Larned *et al*., 2010). A large portion of the global river network is composed of temporary water courses. Their prevalence is furthermore expected to increase in response to global change and increased water uses.

When only the interruption of flow is taken into account for classifying the regimes of these water courses, the exact terminology depends on the methods and the discipline of the author. Hydrologists and environmental scientists usually differentiate between 'intermittent' water courses that have a semi-permanent or seasonal regime with baseflow sustained by groundwater and 'ephemeral' water courses, which convey only water following rainfall or melting events (Leopold and Miller, 1956; Lewick *et al*., 2008). Based on statistical methods, Poff *et al*. (1996) in a study of a wide range of river flow regimes used the term 'intermittent' with other adjectives that describe the increasing duration of no-flow periods (intermittent runoff, intermittent flashy and harsh intermittent). Stream regime classifications specifically designed for temporary rivers take into account not only the continuation and interruption of flow but also the occurrence of water pools that may remain after the cessation of flow, because these pools may extend the continuity of aquatic life during all or part of the period without flow (Uys and O'Keefe, 1997; Gallart *et al*., 2017). In this catalogue the acronym IRES (Intermittent Rivers and Ephemeral Streams) is used to designate any kind of temporary water course.

After years of obscurity, the science of the ecology and hydrology of IRES has bloomed recently and it is now recognised that IRES support a unique high diversity, provide essential ecosystems services and are functionally part of river networks and groundwater systems. Despite the amenity value of these watercourses, they still lack protective and adequate management.

SMIRES is a COST Action addressing the Science and Management of Intermittent Rivers & Ephemeral Streams. This COST Action has brought together scientists from various research fields and stakeholders to develop a European multidisciplinary network for synthesising the fragmented and recent knowledge on IRES, improving our understanding of IRES ecology, and translating this into science-based, sustainable management of river networks. One of the tasks of working group 1 (WG1; "*Prevalence, distribution and trends of IRES*") in the SMIRES COST Action was to compile streamflow data for IRES at the European scale. As part of this work, examples of IRES were collected across Europe, including gauged catchments with both natural and highly influenced flow regimes. A total of 40 examples have been put together in this catalogue to provide an overview of the variety of IRES in Europe. The selected IRES are not meant to be representative of all IRES in Europe, rather the aim of the catalogue is to increase awareness of the existence of IRES and to provide an overview of the variety of flow regimes of IRES in Europe. It is our hope that by putting these examples of IRES together, we not only highlight the variety of IRES in Europe but also contribute to a better understanding of the drivers of the temporariness of streamflow at the European scale. The catalogue includes examples of gauged intermittent rivers, including catchments with both natural and highly influenced river flow regimes. In addition to hydrograph analyses, selected information on the IRES is summarised in a two-page document that includes the examination of the drivers and consequences of their temporariness.

This document is organized as follows. Section 2 introduces the set of IRES included in the catalogue. Section 3 describes the available information for each catchment, while section 4 is a synthesis of the characteristics of the example IRES. Section 5 then includes the actual catalogue of the selected IRES. Note that the terminology has not been systematized for these individual entries of the catalogue. Instead, for the sake of openness, every contributor has used the terms which they commonly use to describe IRES.

2. Datasets

Members of each country involved in the SMIRES Action were invited to provide at least one entry to the catalogue to illustrate intermittence for a gauged site with zero-flow events. The intermittence criteria for the definition of an IRES used by WG1 and SMIRES was: at least one event with observed streamflow not exceeding 1 L/s over five consecutive days. This definition was chosen because of difficulties in actually measuring zero flow (see discussion by Peters *et al*. (2012) and Zimmer *et al*. (2020)). However, it is acknowledged that this definition excludes many of the very small headwater catchments. Note, however, that few of these small streams are gauged (Bishop *et al*., 2008).

The main criteria for selection of the IRES to be included in the catalogue were the available discharge data and knowledge of the dominant processes and drivers of intermittence. We limited the maximum number of entries to five per country. The final selection comprised 40 entries from 15 countries (Bulgaria, Cyprus, France, Greece, Italy, Lithuania, Norway, Poland, Portugal, Serbia, Slovakia, Spain, Switzerland, United Kingdom, also Turkey) (Figure 1). Unfortunately, the catalogue does not cover all of Europe, as the examples were provided by WG1 members.

In addition to the entries for the catalogue, WG1 also collected metadata from gauging stations that meet the intermittence criteria. This database contains information, including flow data period, resolution and availability, from 728 gauging stations from 19 countries. Note that this database is not a complete list of all gauging stations on IRES in Europe but depends on the access to data by the WG1 members. The map with the location of these gauging stations and metadata are available at https://tinyurl.com/SMIRES-gauging-stations[1]. The locations and climate data are plotted in Figure 1 and Section 4 of this document only for comparison with the catchments included in this IRES catalogue.

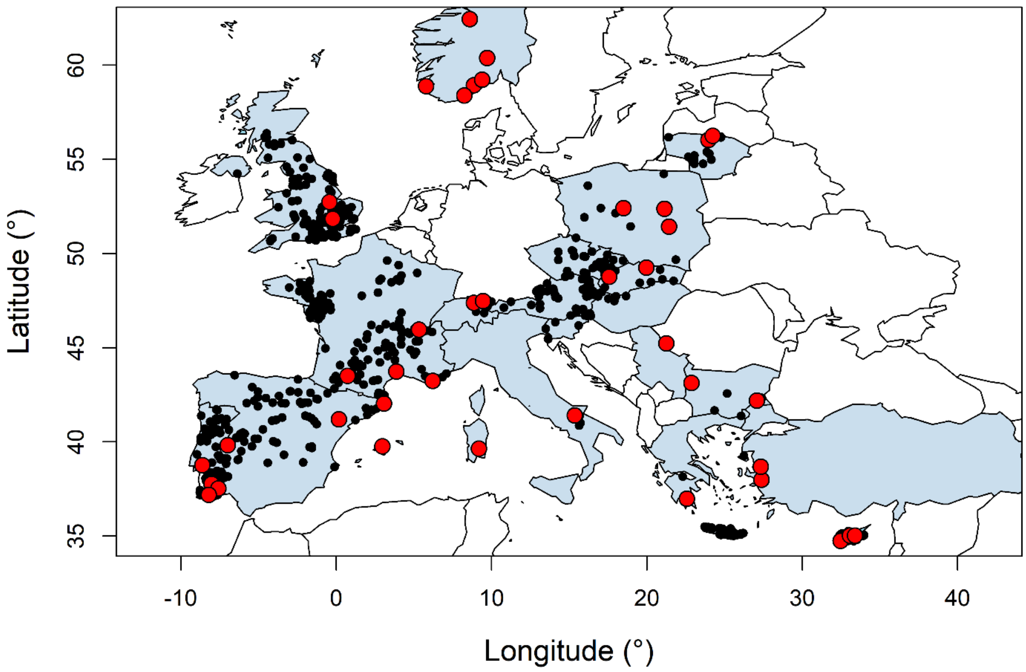

Figure 1: Location of the catchments presented in the catalogue (●) and examples of gauging stations with flow records that met the SMIRES COST Action intermittence criteria (●). Blue shading indicates countries of members involved in data sharing in WG1.

[1] Full link: https://www.google.com/maps/d/viewer?mid=16oqeQgGhW1J6R8uOWBV7vM5Bw5A&ll=46.601150656633905%2C12.514024999999947&z=4

3. Content of the catalogue entries

The same template was used by all members of WG1 for the entries in the catalogue (Figure 2).

On page 1, the first box reports the main basin characteristics (name and coordinates of the gauging station or the outlet of the catchment, land-use, geology, climate, etc.). Two panels display the hydrograph and flow duration curves, for the driest year and the average. A map (upper right) shows the location of the selected gauging station. The first page also includes several photos and a table with relevant metrics on flow intermittence (Table 1). These metrics provide a link with relevant ecological and biochemical processes and allow easy comparison of the flow regimes of the different IRES included in the catalogue.

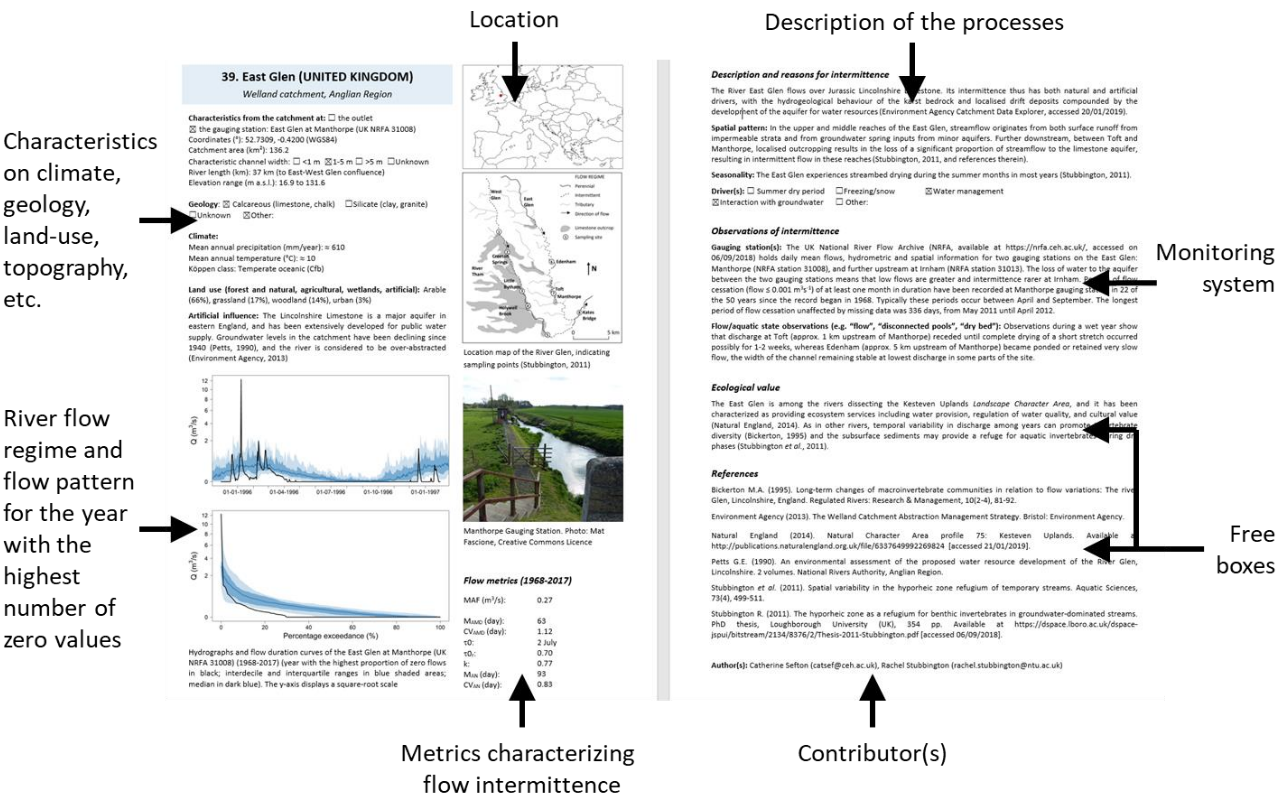

Figure 2: The two-page template used for each entry in the catalogue.

The set of quantitative indices calculated from the streamflow data were selected after discussion with experts within the SMIRES project. The most relevant hydrological indices focus on the dry events and describe the four pillars of the river flow regime (Table 1). The mean annual flow (MAF in m^3/s) was added to this list of metrics as a typical descriptor of the flow regime. All statistics were computed from the time series of daily streamflow using the `SMIRES` R package (https://github.com/mundl/smires).

The calculation of these metrics required several assumptions:

- The hydrological year was fixed to the calendar year,
- All years - even those with incomplete records - have been used,
- To account for potential false-positive detection of zero flows associated with the measurement resolution constraints and uncertainties in discharge observations, “no-flow days” were defined as days for which the daily flow was < 1 L/s,

Pillar	Name / definition	Questions
Duration	**M_{AMD}** (day): Mean duration of the longest annual no-flow event **CV_{AMD}** (dimensionless): Coefficient of variation of the duration of the longest annual no-flow event	*How long does the most severe no-flow event last? How much does this vary between years?*
Timing[2]	**$\tau 0$** (day since January1st)**:** Mean Julian date (day-of-year) of the first annual no-flow day **$\tau 0_r$** (dimensionless): Dispersion around the onset timing (1: no dispersion; 0 evenly distributed)	*When does the first no-flow event occur (seasonality)? How much does this vary between years?*
Rate of change	**k:** Mean rate of decay of the hydrograph during the flow recession periods (a value close to one indicates smooth recession curves, while a value close to zero indicates steep recession curves)	*How quickly is the shift to no-flow approached?*
Frequency	**M_{AN}** (day): Mean annual number of no-flow days **CV_{AN}** (dimensionless): Coefficient of variation of the annual number of no-flow days	*How many days per year is there no-flow? How much does this vary between years?*

Table 1: Description of the metrics describing flow intermittence.

On *page 2* of the catalogue entries, the upper box "*Description and reasons for intermittence*" provides information about the flow intermittence (free text and a short description on the spatio-temporal pattern of no-flow events). The temporal pattern encompasses, for example, seasonal behaviour and observed long-term trends. Spatial patterns may concern flow intermittence observed in different areas of the catchment. The box below "*Observations of intermittence*" describes the monitoring network, including gauging stations and other type of observations (e.g. visual inspection of the flow states at different locations along the river) available for the catchment. Other boxes on this second page, contain free text, including results from research projects, additional studies (not necessary related to physical hydrology) investigated on the catchment, etc. At the bottom of the second page, the name and contact information of the authors is given.

In the following section, the numbers in brackets [ ] refer to the catchment numbers in the catalogue, i.e. in the list presented in Section 8 (page 18).

[2] Both metrics $\tau 0$ and $\tau 0_r$ are circular statistics

4. An overview of the flow regime of the IRES included in the catalogue

Information on climate for each catchment was given by the local experts. We used the Köppen classification proposed by Beck *et al*. (2018) to complete missing climate information. To ensure homogeneity in the following analyses, we used daily mean annual temperature (MAT) and precipitation (MAP), available in the E-OBS high-resolution gridded dataset (Cornes *et al*., 2018).

The selected catchments encompass a wide range of climate conditions with temperature varying from -1°C to 19°C and total precipitation from 300 mm/year to 1700 mm/year (Figure 3). The examples include IRES in Subpolar oceanic climate Cfc [15] to temperate Mediterranean climate Csa [e.g. 4, 8, 9, 11, 27, 33, 38]. The majority of selected streams have a Csa climate (near 40%). The selected IRES reflect a large part of the various types of climate in Europe. However, a large proportion of the selected IRES (i.e. the dots on Figure 3) are located outside of the area defined by the 25% contour level of climates in Europe and there is no catchment included in the catalogue with temperatures less than 5°C and precipitation less than 500 mm/year (i.e. countries and climates in eastern Europe). Despite the uneven distribution of the catchments identified by WG1 members, Figure 3 clearly demonstrates that IRES are not limited to the warm-dry climates, as frequently misjudged.

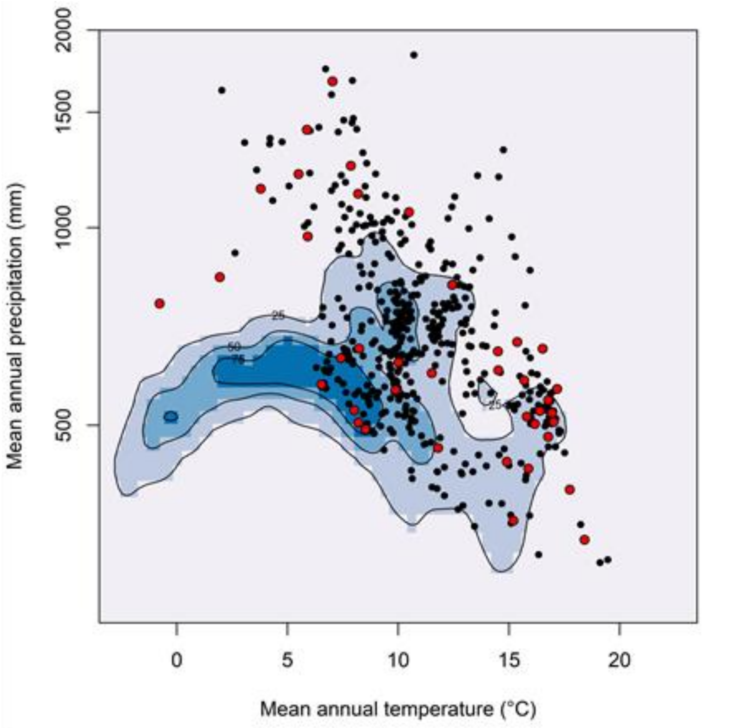

Figure 3: Bivariate density plot of mean annual temperature and mean annual precipitation with 25%, 50% and 75% probability contour levels based on temperature and total precipitation extracted from the E-OBS database between latitude 34° and 70°N and longitude -20° and 40°W. Red dots represent catchments included in the catalogue (●) while smaller black dots represent the gauging stations with flow in the larger database of gauging stations (●).

The empirical distribution function of the mean annual number of no-flow days M_{AN} (Figure 4) shows that the catalogue includes only two highly intermittent (ephemeral) streams that typically flow for fewer than 90 days per year [4, 32]. By contrast, nearly half of the selected IRES (17 of the 40 selected examples) are weakly intermittent, with on average no-flow on fewer than 30 days during the year.

Intermittent streams are not exclusive to arid and Mediterranean climates. However, there is a tendency, although weak, for the duration and frequency of no-flow metrics - M_{AMD} and M_{AN} - to increase as mean annual temperature increases (R^2(M_{AMD}, MAT) and R^2(M_{AM}, MAT) > 0.35), and as mean annual precipitation decreases (R^2(M_{AMD}, MAP) and R^2(M_{AM}, MAP) > 0.13; Figure 6). Highly intermittent streams are mostly found in arid climates.

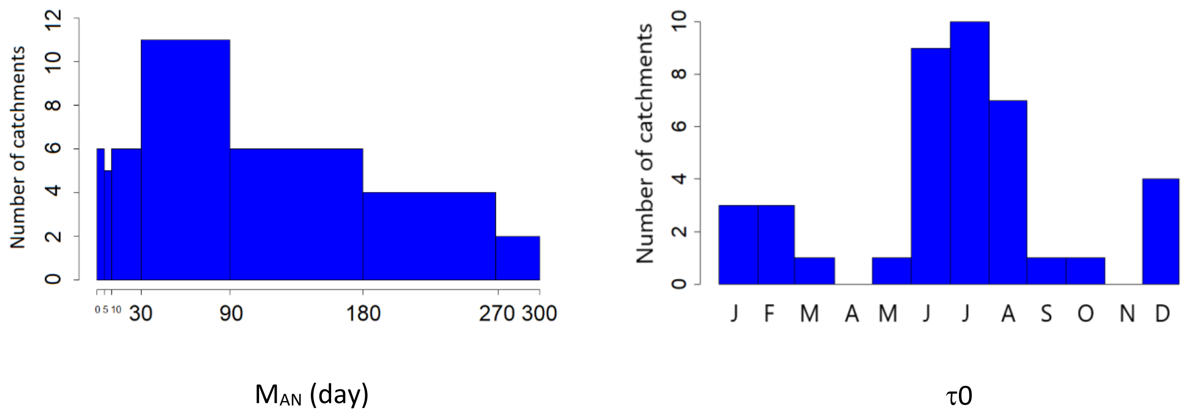

Figure 4: Empirical distribution of the mean annual number of no-flow days M_{AN} and the frequency distribution of the mean onset timing $\tau 0$ for the IRES included in the catalogue.

The frequency distribution of the mean onset timing $\tau 0$ (Figure 4) reveals a clear bimodal distribution. The dominant cluster contains catchments with no-flow periods usually starting in late spring and summer. The other cluster includes catchments with $\tau 0$ in winter (between December and March). It contains two examples with intermittence due to freezing or snow processes [16, 21], two with intermittence due to human influences [34, 35], and most intermittent streams with M_{AN} > 200 days per year [2, 4, 7, 24, 27, 32]. For these ephemeral streams, the values for the timing $\tau 0$ are highly sensitive to the choice of the start of the hydrological year. Due to the large portion of no-flow days, the probability of observing no-flow conditions is high throughout the year and values of $\tau 0$ for these catchments are close to the first day of the chosen hydrological year. Because of the relevance of onset timing for freshwater biologists, an unbiased method to characterize this characteristic needs to be found.

The set of 40 examples covers a high diversity of geological contexts. Geological characteristics are not commented upon here but are available for later uses. Indeed the qualitative information provided in the two-page documents was not straightforwardly interpretable in terms of consequence for flow intermittence.

From the box "*Description and reasons for intermittence*", no-flow conditions are mostly observed in summer and autumn. Dry conditions and human influences are the main causes of flow intermittence for 38 of the selected catchments. The occurrence of a "*Summer dry period*" is the main driver of intermittence (cited 30 times). "*Water management*" and "*Interaction with groundwater*" were considered equally frequent as the possible origin for no-flow, with a similar but lower proportion than "*Summer dry period*" (around 16 times). The example of the Matarranya River [34] illustrates the case of a perennial river that has changed to an intermittent due to water abstractions for irrigation.

There is a strong correlation between the mean duration of the longest annual no-flow event (M_{AMD}) and the mean annual number of no-flow days (M_{AN}) (R^2(M_{AMD}, M_{AN}) = 0.92; Figure 5). The variability in the mean annual number of no-flow days and the duration of longest annual no-flow event are also highly correlated (R^2(CV_{AMD}, CV_{AN}) = 0.99), suggesting that for most of the selected catchments there is one long zero-flow event within a year. For three of the selected catchments [7, 32, 33] this is not the case. These are Mediterranean highly intermittent streams (M_{AN} > 130 days per year) and heavy rainfall events may interrupt no-flow conditions. Dispersion in the number of no-flow days and the length of the longest no-flow period (CV_{AN} and CV_{AMD}) is high for rare to moderately intermittent streams (e.g. CV_{AN} varies from 0.84 to 6.71 when $M_{AN} \leq 12$ days per year), suggesting low year-to-year predictability of no-flow conditions. Note that the two metrics CV_{AMD} and CV_{AN} are related to M_{AMD} and M_{AN} but not linearly (Figure 5).

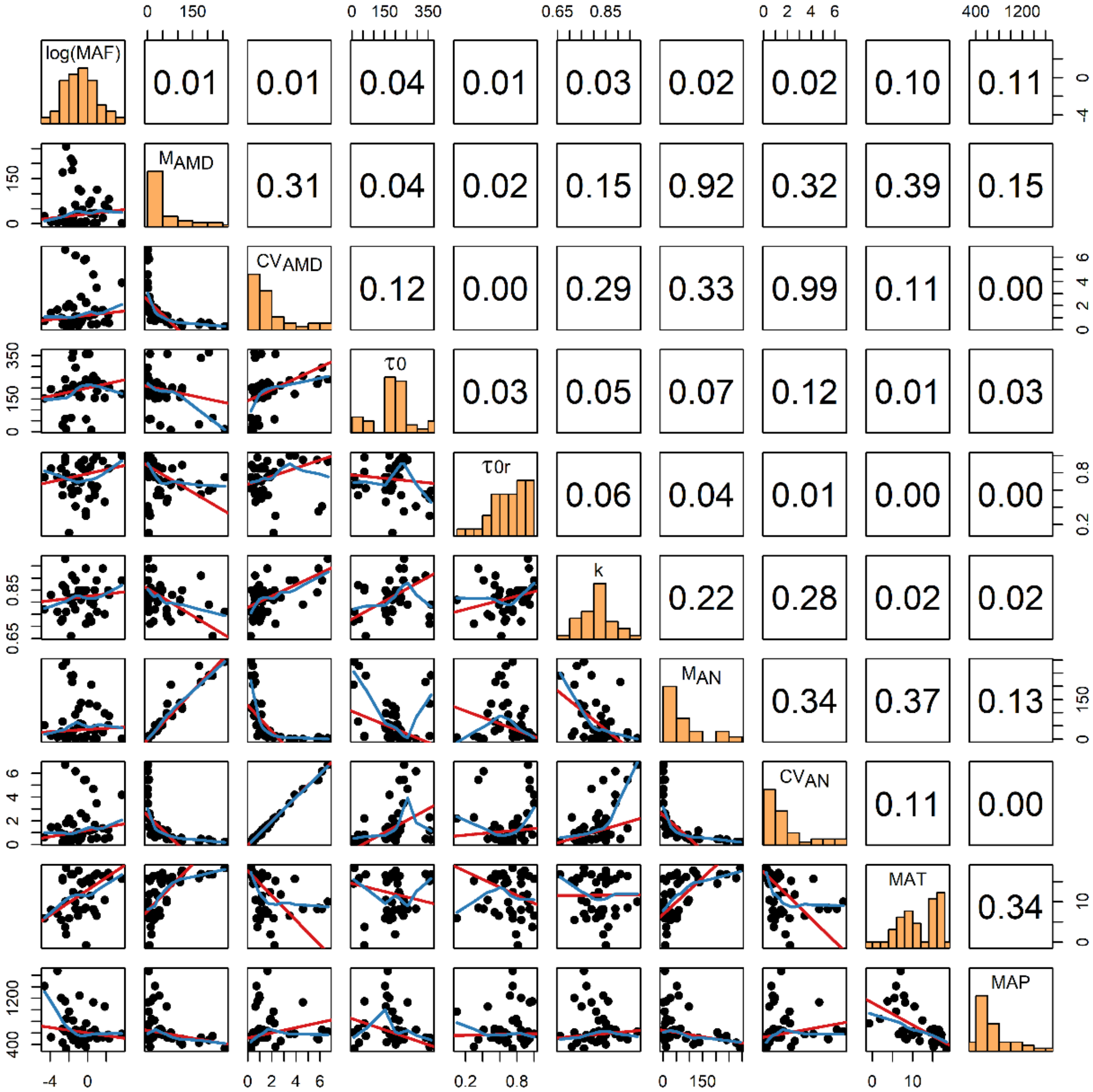

Figure 5: Scatter plots and coefficients of determination (R^2) for selected hydrological and climate metrics (see Table 1 for the definition of the variables and units). Regression line and lowess smoothing are shown in red and in blue, respectively.

The maximum value of the recession constant k was calculated for the Thames River basin [40], while the minimum value was calculated for the Portuguese part of the Guadiana River basin [27]. The two examples highlight the difference in the contribution of groundwater to streamflow, combined with more the difference in the precipitation regime. The recession constant k is weakly to moderately negatively correlated with most of the calculated no-flow characteristics: M_{AMD}, M_{AN} (R^2(k, M_{AMD}) = 0.15 and R^2(k, M_{AN}) = 0.22, Figure 6), CV_{AMD} and

CV_{AN} (R^2(k, CV_{AMD}) and R^2(k, CV_{AN}) ≥ 0.28) (Figure 5). Highly intermittent rivers are characterized by steep declines in streamflow and a uniform probability of no-flow duration within each year (Figure 6).

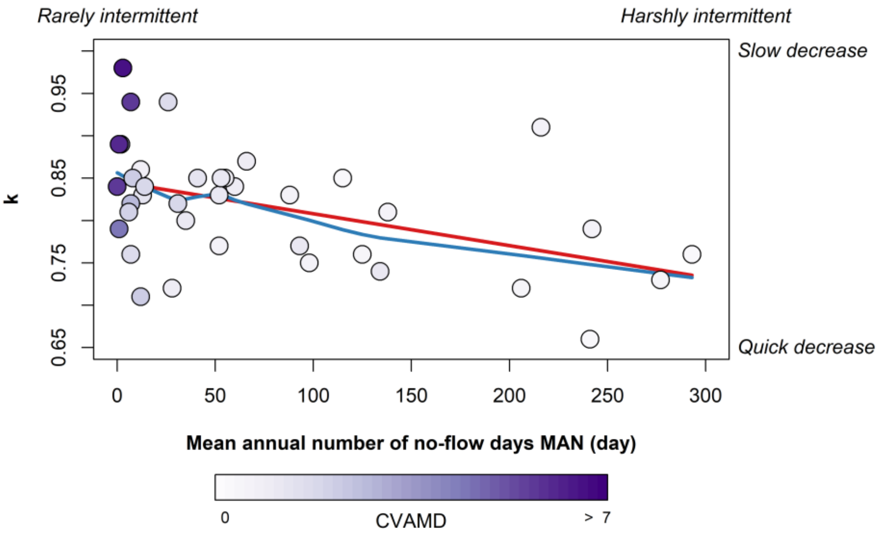

Figure 6: Relationship between the recession constant (k) and the mean annual number of no-flow days (M_{AN}) for the catchments included in the catalogue. The symbol colour indicates the variability in the duration of longest annual no-flow event (CV_{AMD}). Regression line and lowess smoothing are displayed in red and in blue, respectively.

The maps of the intermittence characteristics (Figure 7) highlight the variability of flow intermittence characteristics across Europe. The map of M_{AN} also provides the values from the large dataset of gauging stations for comparison. This is the only metric that is available in the metadata of these 728 gauged catchments. The spatial distribution of values of M_{AN} highlights the spatial heterogeneity of temporariness, which is less evident on the other maps due to the sparseness of the dataset. Consistent with a dry climate and the link to MAT, high values of M_{AN} are more likely in Southern Europe.

Spatial patterns of flow intermittence are described for some of the selected IRES. These patterns highlight the heterogeneity in flow conditions at the local scale: intermittence observed in the whole course [e.g. 1, 8, 9, 13, 26, 29, 33], gradually increasing from upstream to downstream [e.g. 2, 5, 11, 31, 40], and gradually decreasing from upstream to downstream [e.g. 6, 23, 30, 37]. These patterns can be due to human actions (e.g. water abstraction [9, 37]) or geological peculiarities (e.g. infiltration into the alluvium [5]). No-flow conditions are mostly observed in headwaters, while perennial reaches are more prominent in the downstream part of the catchments but the catalogue demonstrate that counter-examples can be found.

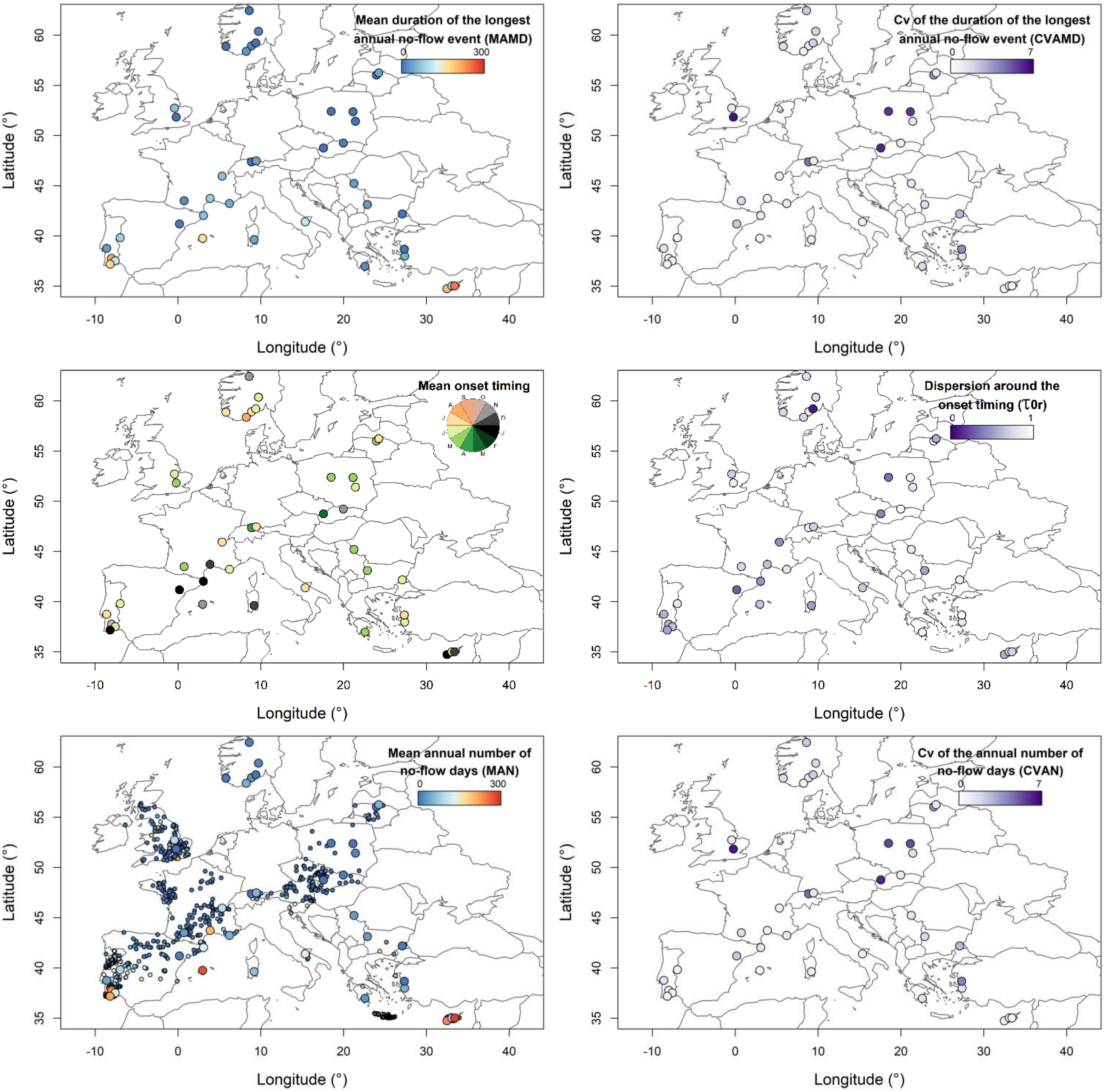

Figure 7: Maps showing the locations of the catchment included in the catalogue and the values of the metrics. See Table 1 for the description of the metrics. The small dots in the map of M_{AN} are basins included in the larger dataset of 728 gauged catchments.

5. Closing words

The entries in the catalogue highlight the variety of IRES in Europe. The selection of IRES is not representative of all IRES in Europe as examples from some countries and climates are missing (e.g. northern Scandinavia), and the chosen definition of no-flow events led to the exclusion of many small headwater catchments. However, the selected IRES do provide an overview of the different flow regimes and drivers of intermittence across Europe. We therefore hope that the catalogue will increase the appreciation of IRES in Europe and is a useful basis for future initiatives on temporary water courses (e.g. extending the sample of European intermittent rivers and ephemeral streams).

The initial analyses of the flow metrics for these selected IRES highlight the variability in the flow regimes of IRES in Europe and also highlight the need for more flow data for IRES. Few gauging stations are located in headwater catchments (Bishop *et al*., 2008), limiting the availability of flow data for these streams. Other ways to obtain data on no-flow events in streams are being explored, including low-cost sensors (e.g. Assendelft and van Meerveld, 2019; Paillex *et al*., 2020) and citizen science approaches (e.g. Kampf *et al*., 2018). The definition of a no-flow event is difficult for many gauging stations due to uncertainties in the data (Peters *et al*., 2012; Zimmer *et al*., 2020). Therefore, additional efforts for quality control of low flow data for existing gauging stations is needed to define no-flow periods as well.

6. Acknowledgments

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8. The catalogue

List of catchments:

COUNTRY	River basin	Number
BULGARIA	Fakiiska	1
CYPRUS	Ezousa	2
	Peristerona	3
	Yialias	4
FRANCE	Albarine	5
	Lauze	6
	Lirou	7
	Réal Collobrier	8
GREECE	Evrotas	9
ITALY	Celone	10
	Rio Mulargia	11
LITHUANIA	Daugyvenė	12
	Yslykis	13
NORWAY	Brusetbekken	14
	Gramstaddalen	15
	Håkådalselv	16
	Langtjernbekk	17
	Tjellingtjernbekk	18
	Tveitdalen	19
POLAND	Czarna	20
	Goryczkowy Potok	21
	Noteć	22
	Zagożdżonka	23
PORTUGAL	Algibre	24
	Almansor / Ribeira de Santo Estevão / Ribeira de Canha	25
	Erges	26
	Terges	27
	Vascão	28
SERBIA	Moravica	29
	Visočica	30
SLOVAKIA	Myjava	31
SPAIN	Búger	32
	Daró	33
	Matarranya	34
SWITZERLAND	Mühlebach	35
	Töss	36
TURKEY	Gediz	37
	Küçük Menderes	38
UNITED KINGDOM	East Glen	39
	Mimram	40

1. Fakiiska (BULGARIA)

Black Sea Region

Characteristics from the catchment at: ☒ the outlet
☐ the gauging station:
Coordinates (°): 42.394862, 27.390576 (WGS84)
Catchment area (km²): N.A.
Characteristic channel width: ☐ <1 m ☐1-5 m ☒ >5 m ☐Unknown
River length (km): 78
Elevation range (m a.s.l.): 14 to 717

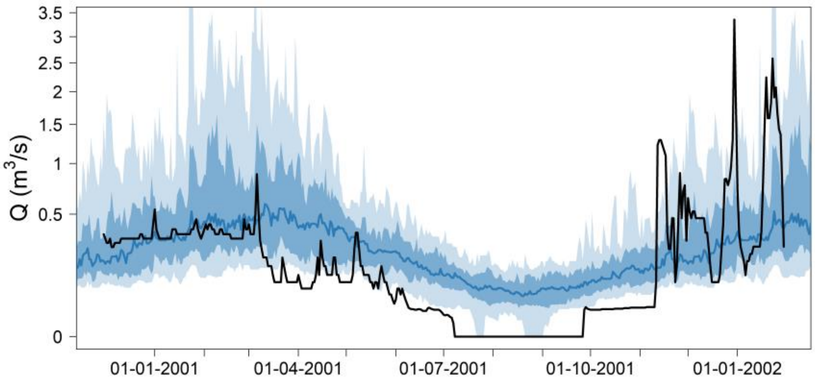
Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒Other: Sedimentary

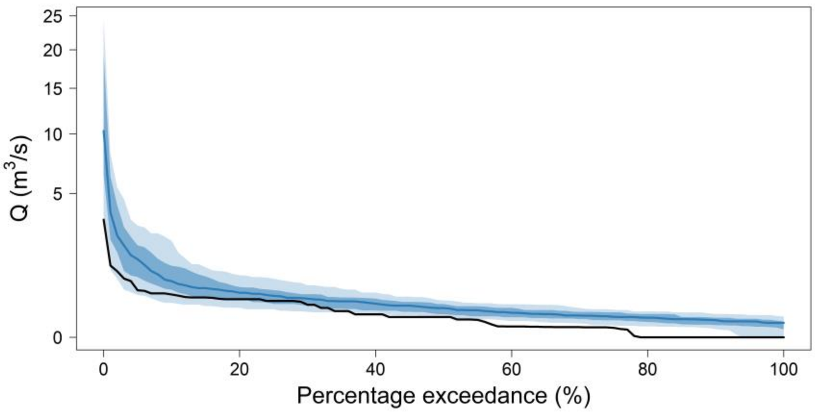
Climate:
Mean annual precipitation (mm/year): 600
Mean annual temperature (°C): 11
Köppen class: Warm oceanic climate (Cfa)

Land use (forest and natural, agricultural, wetlands, artificial): Non-irrigated arable land in the headwaters; forest and agricultural in the downstream part

Artificial influence: Minimal

Upper section of the Fakiiska River at the Fakia gauging station in flowing phase. Photo taken by Tzviatka Karagiozova, date: 18/09/2017, coordinates: 42.183314°, 27.080375°





Hydrographs and flow duration curves of the Fakiiska River at Fakia (1976-2016) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Lower section of the Fakiiska River at the Zidarevo gauging station in flowing phase. Photo taken by Tzviatka Karagiozova, date: 19/09/2017, coordinates: 42.337269°, 27.412612°

Flow metrics (1976-2016)

MAF (m^3/s):	0.50
M_{AMD} (day):	6
CV_{AMD} (day):	2.72
τ0:	31 July
$τ0_r$:	0.92
k:	0.82
M_{AN} (day):	7
CV_{AN} (day):	2.62

Description and reasons for intermittence

Fakiiska is a representative river for the hydrology in the south-eastern Bulgaria. The river has a strong interannual irregularity. The river flows in the non-aquiferous formations with a weak recharge.

Spatial pattern: Intermittent in the whole course.

Seasonality: The river dries up in the period between July and October. During this process, isolated pools usually remain and a total dry riverbed is rarely observed.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☐Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): Along the Fakiiska River, there are two gauging stations near Fakia and Zidarevo villages. The stations are part of the hydrometric network of Bulgaria and are maintained by the National Institute of Meteorology and Hydrology.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): The collected information concerning the Fakiyska River discharge is a result of the regular measurements carried out by the National Institute of Meteorology and Hydrology in the two gauging stations - from 1955 for the Fakia gauging station and from 1951 for the Zidarevo gauging station. There are three main phases in the upper stream (Fakia station) - flow, drying with isolated ponds and dry river basin. In the lower stream (Zidarevo station) two phases of flow and drying with isolated pools are registered.

Ecological value

The water of the Fakiiska River has a good ecological value (River Basin Management Plan of the Black Sea Basin Directorate (2016-2021)). There are protected areas in the Fakiiska River basin.

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2. Ezousa (CYPRUS)

Southwestern Troodos Mountains to Mediterranean Sea

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Ezousa at Akhelia
Coordinates (°): 34.7390, 32.4797 (WGS84)
Catchment area (km²): 207.7
Characteristic channel width: ☐ <1 m ☐1-5 m ☒ >5 m ☐Unknown
River length (km): 46.1
Elevation range (m a.s.l.): 27 to 1362

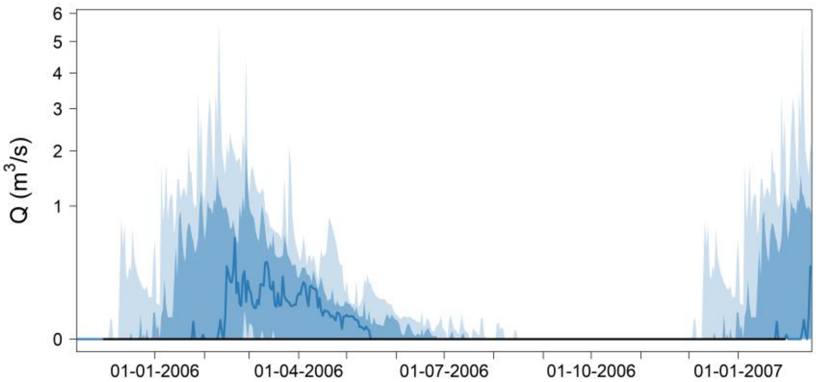
Flow gauging station on Ezousa River near Akhelia. Photo: Gerald Dörflinger; date: February 2009

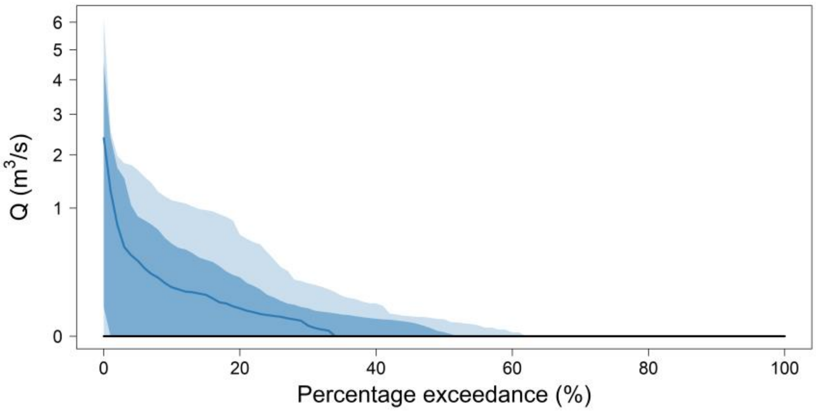
Geology: ☒ Calcareous (limestone, chalk) ☐Silicate (clay, granite) ☐Unknown ☒ Other: Troodos ophiolite complex (upper catchment), non-calcareous sedimentary rocks (middle and lower catchment)

Climate:
Mean annual precipitation (mm/year): 597
Mean annual temperature (°C): 17.3
Köppen class: Hot-summer Mediterranean climate (CSa)

Land use (forest and natural, agricultural, wetlands, artificial): Forest and natural (49%), agricultural (48%), artificial (3%) (source: Corine Land Cover 2006)

Artificial influence: A stream intake of the Paphos Irrigation Project (since 1991) and Kannaviou Dam (since 2005) are in operation





Hydrographs and flow duration curves of the Ezousa at Akhelia (2004-2014) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Ezousa river valley at Episkopi village (https://www.paphoslife.com/images/blog/ezousa_valley/01_episkopi.jpg)

Flow metrics (2004-2014)

MAF (m^3/s):	0.21
M_{AMD} (day):	204
CV_{AMD} (day):	0.55
$\tau 0$:	28 December
$\tau 0_r$:	0.59
k:	0.79
M_{AN} (day):	242
CV_{AN} (day):	0.42

Description and reasons for intermittence

Springs and river water in the headwaters are used for domestic water supply thus flow in the small streams is reduced mainly over the dry period. Flow regime is strongly modified downstream of the Kannaviou Reservoir. The Ammati (karstic gypsum) spring discharges into the middle reaches, rendering the river perennial for about 5 km length. Intermittency is increased by a stream diversion in the lower reaches.

Spatial pattern: Headwaters do not fall dry, pools persist over summer. Ayia Forest Station until Ammati spring: intermittent, with much reduced flow rates downstream of Kannaviou Dam. Downstream of Ammati spring: perennial, then gradually becoming intermittent and ephemeral due to infiltration into the alluvium. Tributaries are ephemeral.

Seasonality: In the intermittent reaches the dry period is August-November upstream of Kannaviou Reservoir but much longer downstream of the dam. Flow in the ephemeral lower reach most frequently occurs between January and April.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☒Water management
☒Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): Five gauging stations are currently in operation in the catchment: Ayia Forest Station, upstream of Kannaviou Reservoir, Kannaviou (not shown here), Moro Nero and Akhelia (2.5 km from river mouth).

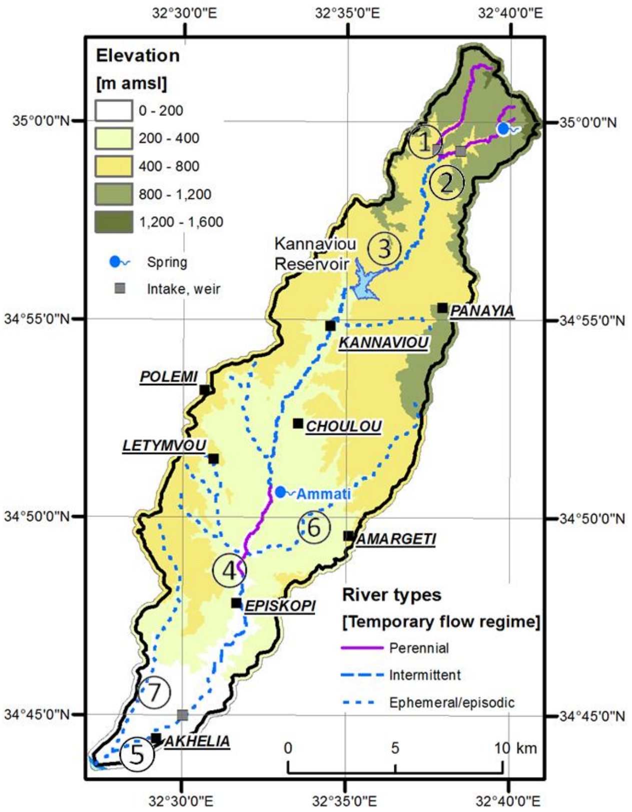
Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): Aquatic state (Gallart *et al*., 2012) is monitored in the catchment since 2015 at all gauging stations and in all tributaries. Streamflow and aquatic state data were evaluated using the TREHS software (Gallart *et al*., 2017) and are shown on the triangular plot below.

Gallart *et al.* (2012). A novel approach to analysing the regimes of temporary streams in relation to their controls on the composition and structure of aquatic biota. Hydrology and Earth System Sciences, 16(9), 3165–3182.

Gallart *et al.* (2017). TREHS: An open-access software tool for investigating and evaluating temporary river regimes as a first step for their ecological status assessment. Science of the Total Environment, 607–608, 519–540.

Ecological value

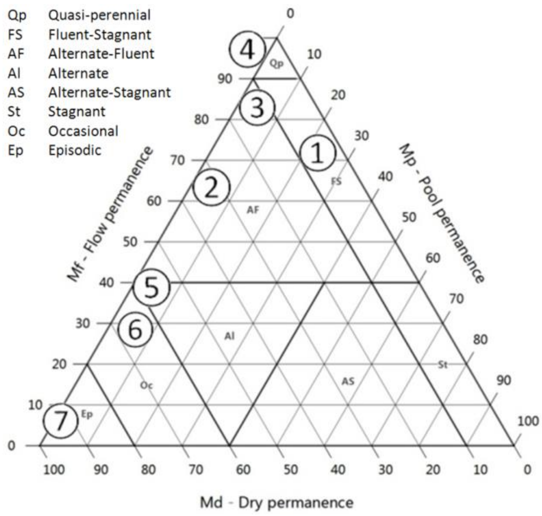
The perennial reach downstream of the Ammati spring is perhaps the most important of the few remaining habitats of the European eel (*Anguilla anguilla*) in Cyprus rivers. Influx of young eels from the sea into the perennial river section is possible only when the intermittent and ephemeral lower river reaches have flow and discharge into the sea.



Catchment map and Flow-Pools-Dry (FPD) plot

Observation sites:

1. Argaki Klimadhiou upstream Ayia Forest Station
2. Ayia river near Ayia Forest Station
3. Ayia river upstream Kannaviou Reservoir
4. Ezousa river near Moro Nero
5. Ezousa river near Akhelia
6. Varkas River near Amargeti
7. Kochatis River near Koloni



Author(s): Gerald Dörflinger (gdorflinger@wdd.moa.gov.cy)

3. Peristerona (CYPRUS)

Northern Troodos Mountains to the Western Mesaoria Plain

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Peristerona at Panayia Bridge
Coordinates (°): 35.0196, 33.0819 (WGS84)
Catchment area (km²): 77.4
Characteristic channel width: ☐ <1 m ☒1-5 m ☐ >5 m ☐Unknown
River length (km): 23.4
Elevation range (m a.s.l.): 414 to 1554

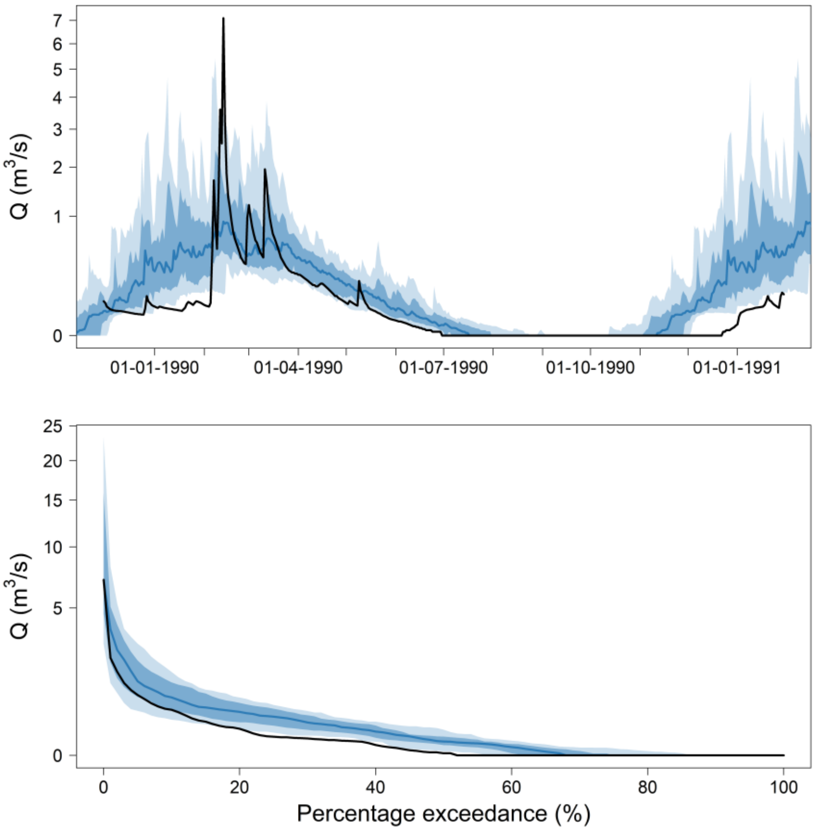
Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒ Other: Troodos ophiolite complex

Climate:
Mean annual precipitation (mm/year): 615
Mean annual temperature (°C): 15.3
Köppen class: Hot-summer Mediterranean climate (CSa)

Land use (forest and natural, agricultural, wetlands, artificial): Forest and natural (77%), agricultural (22.5%), artificial (0.5%) (Corine Land Cover 2006)

Artificial influence: Apart from abstraction for irrigation and water supply in the upper catchment (from boreholes, springs and intakes), it is one of the very few sizeable catchments with largely natural flow regime in Cyprus

Flow gauging station on Peristerona River near Panayia Bridge. Photo Gerald Dörflinger; date: March 2013



Hydrographs and flow duration curves of the Peristerona at Panayia Bridge (1970-2000) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Gabion weir with recharge pond near Orounta village in the lower reach of the river. Photo Gerald Dörflinger; date: May 2013

Flow metrics (1970-2000)

MAF (m^3/s):	0.38
M_{AMD} (day):	115
CV_{AMD} (day):	0.32
τ:	19 July
τ_r:	0.89
k:	0.85
M_{AN} (day):	115
CV_{AN} (day):	0.31

Description and reasons for intermittence

Peristerona is a naturally temporary river along its entire course. In the upper catchment (mountain villages) water is abstracted from boreholes, springs and stream intakes for irrigation and water supply. Even though agriculture in this mountainous area with steep narrow valleys is not intensive, the abstractions have some impact on flows in late spring and summer, especially during dry years. Between the mountain villages and Panayia Bridge gauging station, a large area is under natural pine forest without artificial impact on hydrology. Downstream of the Panayia Bridge gauging station, alluvial deposits become significant and their thickness increases towards downstream; transmission losses increase analogously and the river becomes ephemeral/episodic in its lower reaches; in this section, a number of in-stream recharge ponds constructed for aquifer recharge enhance infiltration of surface flow into the river bed and the aquifer.

Spatial pattern: Intermittency decreases from the headwaters until the exit from the narrow river valley downstream of Panayia Bridge, and from there towards downstream it increases as the valley opens up and transmission losses increase.

Seasonality: The hyporheic period (*i.e.* streambed devoid of water) near Panayia Bridge, on average, starts in July and lasts until October/November. The intermittent reaches upstream and downstream of Panayia Bridge dry up earlier and stay dry until later in autumn. Flow in the ephemeral/episodic lower reaches most frequently occurs between January and March.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☒Water management
☒Interaction with groundwater ☐Other:

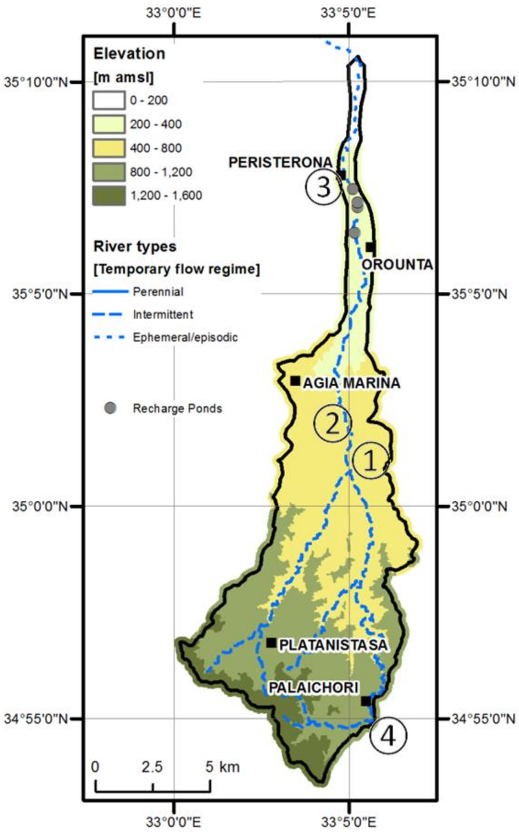
Observations of intermittence

Gauging station(s): One hydrometric station, near Panayia Bridge, is in operation in the catchment.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): Aquatic state (Gallart *et al*., 2012) is monitored in the catchment since 2015 at four sites, including at Panayia Bridge hydrometric station. Stream flow and aquatic state data were evaluated using the TREHS software (Gallart *et al.*, 2017) and are shown on the triangular plot below.

Gallart *et al*. (2012). A novel approach to analysing the regimes of temporary streams in relation to their controls on the composition and structure of aquatic biota. Hydrology and Earth System Sciences, 16(9), 3165–3182.

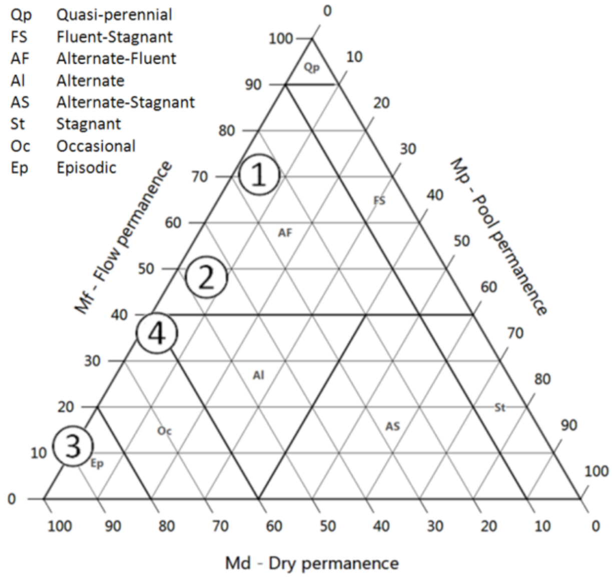
Gallart *et al*. (2017). TREHS: An open-access software tool for investigating and evaluating temporary river regimes as a first step for their ecological status assessment. Science of the Total Environment, 607–608, 519–540.



Catchment map and Flow-Pools-Dry (FPD) plot

Observation sites:

1. Peristerona River near Panayia Bridge
2. Peristerona River at Siphilos
3. Peristerona River at Peristerona
4. Palaichori River at Khalkomatas



Author(s): Gerald Dörflinger (gdorflinger@wdd.moa.gov.cy)

4. Yialias (CYPRUS)

Eastern Troodos Mountains to Eastern Mesaoria Plain

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Yialias at Nisou
Coordinates (°): 35.0197, 33.3952 (WGS84)
Catchment area (km²): 92.5
Characteristic channel width: ☐ <1 m ☐1-5 m ☒ >5 m ☐Unknown
River length (km): 31.2
Elevation range (m a.s.l.): 230 to 1423

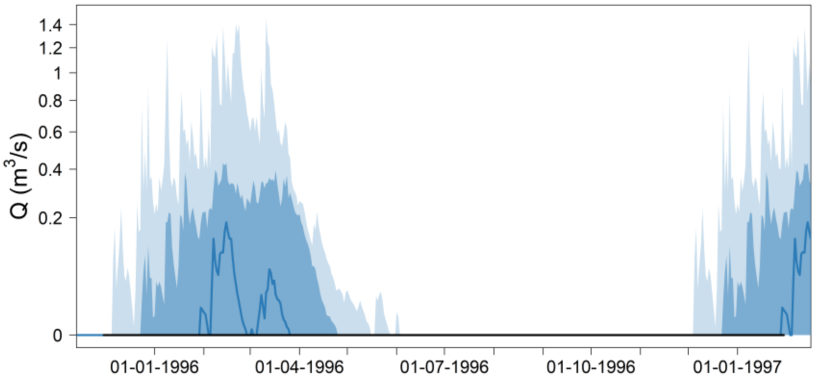
Yialias river just upstream of the flow gauging station in Nisou. Photo: Gerald Dörflinger; date: February 2010

Geology: ☒ Calcareous (limestone, chalk) ☐Silicate (clay, granite) ☐Unknown ☒Other: Troodos ophiolite complex (upper and middle catchment), gypsum alternating with marls and chalks (lower catchment)

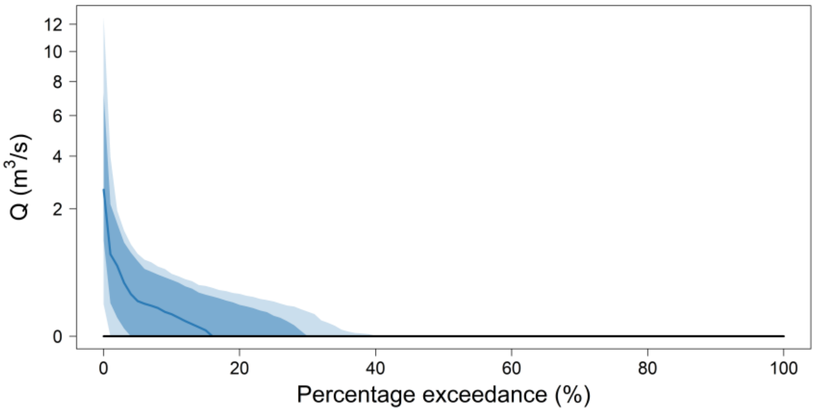
Climate:
Mean annual precipitation (mm/year): 430
Mean annual temperature (°C): 17.5
Köppen class: Hot-summer Mediterranean climate (CSa)

Land use (forest and natural, agricultural, wetlands, artificial): Forest and natural (47%), agricultural (47%), artificial (6%) (source: Corine Land Cover 2006)

Artificial influence: There are seven in-stream recharge ponds for groundwater recharge and two small dams upstream of the Nisou gauging station



Yialias river valley, middle reach upstream of Kotsiatis flow gauging station. Photo: Gerald Dörflinger; date: September 2011



Hydrographs and flow duration curves of the Yialias at Nisou (1970-2000) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Flow metrics (1970-2000)

MAF (m^3/s):	0.10
M_{AMD} (day):	257
CV_{AMD} (day):	0.29
$\tau0$:	11 June
$\tau0_r$:	0.75
k:	0.76
M_{AN} (day):	293
CV_{AN} (day):	0.23

Description and reasons for intermittence

Yialias is a naturally temporary river along its entire course. The headwaters are under natural pine forest. In its middle reaches, the river flows over volcanic rocks (pillow lavas) with low permeability; in this section, pools persist somewhat longer than is normally the case in the lowland rivers of Cyprus. The ephemeral-episodic regime in the lower reaches is partly due to infiltration into the river alluvium and into large karstified gypsum lenses that are present in the underlying Miocene sedimentary formations. Large sinkholes exist and water management aims to keep aquifer water levels high to avoid further collapsing of cavities in the gypsum lenses, hence the recharge ponds (gabion weirs) along the lower river course were constructed.

Spatial pattern: The river is intermittent in its upper and middle reaches, and intermittency decreases towards downstream. Downstream of the Kotsiatis flow gauge, transmission losses into the alluvial deposits and into the gypsum lenses render the river ephemeral/episodic.

Seasonality: The hyporheic period (i.e. streambed devoid of surface water) at the Kotsiatis flow gauge, on average, starts in August and lasts until November. Intermittent reaches further upstream dry up earlier. Flow in the ephemeral/episodic lower reaches most frequently occurs between January and March.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☒Water management

☒Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): Three gauging stations operate in the Yialias catchment, near Kotsiatis, near Nisou and near Potamia.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): Aquatic state (Gallart *et al*., 2012) is monitored in the catchment since 2015 at all hydrometric stations and at one additional observation point in the upper reaches at Azisis locality. Stream flow and aquatic state data were evaluated using the TREHS software (Gallart *et al*., 2017) and are shown on the triangular plot below.

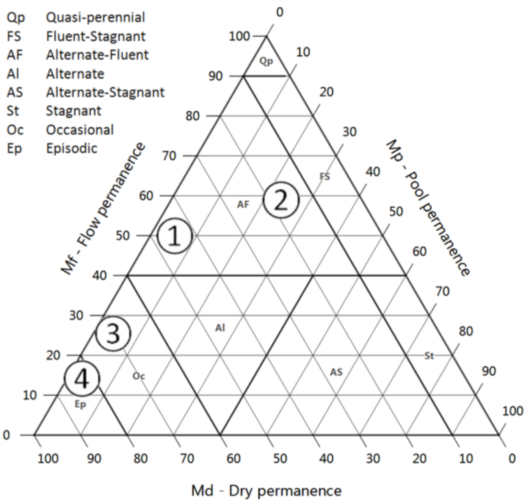
Gallart *et al*. (2012). A novel approach to analysing the regimes of temporary streams in relation to their controls on the composition and structure of aquatic biota. Hydrology and Earth System Sciences, 16(9), 3165–3182.

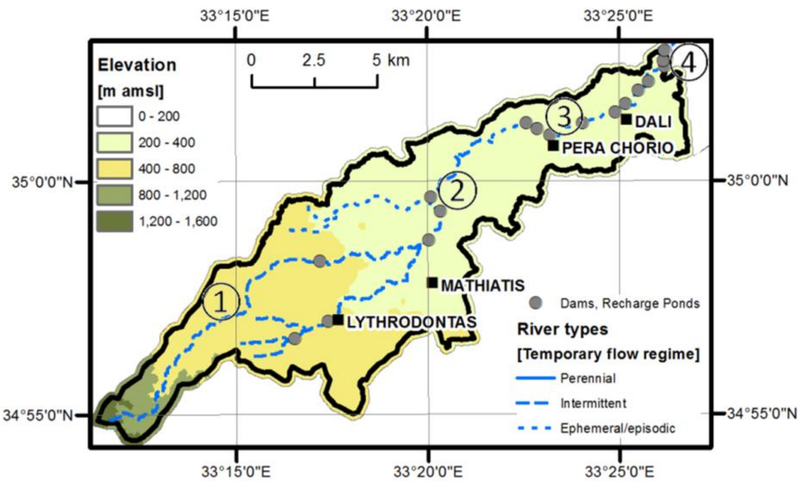
Gallart *et al*. (2017). TREHS: An open-access software tool for investigating and evaluating temporary river regimes as a first step for their ecological status assessment. Science of the Total Environment, 607–608, 519–540.

Catchment map and Flow-Pools-Dry (FPD) plot

Observation sites:

1. Yialias River at Azizis locality
2. Yialias River near Kotsiatis
3. Yialias River near Nisou
4. Yialias River near Potamia





Author(s): Gerald Dörflinger (gdorflinger@wdd.moa.gov.cy)

5. Albarine (FRANCE)

French part of the Rhone River basin

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Albarine at Saint-Denis-en-Bugey (V2934010)
Coordinates (°): 45.9544, 5.3324 (WGS84)
Catchment area (km²): 288
Characteristic channel width: ☐ <1 m ☒1-5 m ☐ >5 m ☐Unknown
River length (km): ≈ 50
Elevation range (m a.s.l.): 239 to 1240

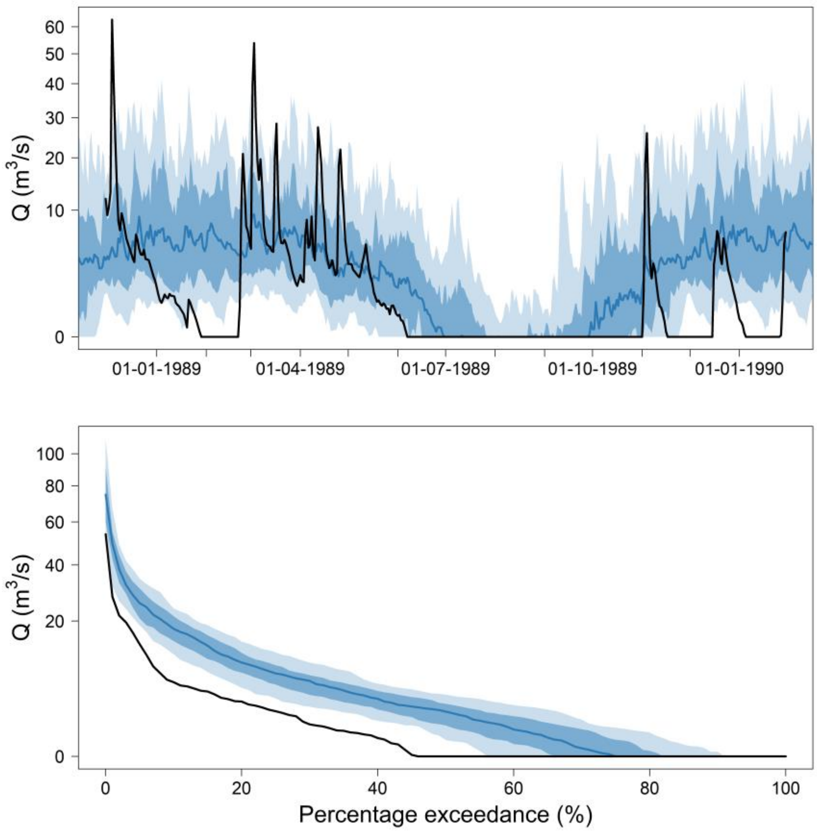
Geology: ☒ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☐Other:

Climate:
Mean annual precipitation (mm/year): 1700
Mean annual temperature (°C): 8
Köppen class: Temperate oceanic climate (Cfb)

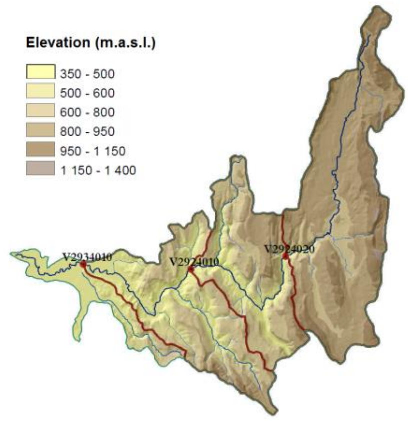
Land use (forest and natural; agricultural; wetlands; artificial): Forest (62%), agriculture (27%) (source: Corine Land Cover 2006)

Influence: No regulation, groundwater abstractions for irrigation in the in the downstream part and domestic uses in the upstream part

Dry bed observed in September 2012 (http://www.basserivieredain.com)



Hydrographs and flow duration curves of the Albarine at Saint-Denis-en-Bugey (1981-2018) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale



The Albarine River basin and the sub-basins defined by the three gauging stations available on the catchment

Flow metrics (1981-2018)

MAF (m³/s):	6.29
M_{AMD} (day):	63
CV_{AMD} (day):	0.64
$\tau 0$:	3 June
$\tau 0_r$:	0.46
k:	0.75
M_{AN} (day):	98
CV_{AN} (day):	0.48

Description and reasons for intermittence

The Albarine River basin is located in eastern France. The Albarine River (313 km² at its mouth) rises in a forested, limestone plateau of the Jura Mountains. The river flow regime is partly influenced by snow melt processes in the upper part of the basin due to high elevation. The Albarine River is a ~12 km ephemeral reach flowing over the small alluvial floodplain underlain by thick and highly permeable alluvium before merging with the Ain River. Losses to the underlying aquifer are observed for most of its downstream course.

Spatial pattern: Intermittent in the downstream part.

Seasonality: Flow ceases mainly in summer every year.

Driver(s): ☐ Summer dry period ☐Freezing/snow ☒Water management
☒Interaction with groundwater ☐ Other:

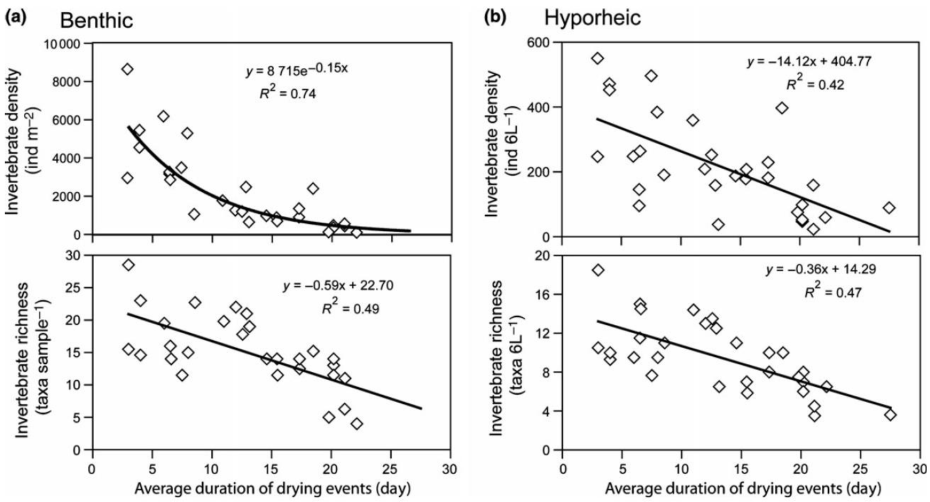
Observations of intermittence

Gauging station(s): There are three gauging stations in the Albarine River basin (http://www.hydro.eaufrance.fr/). The uppermost station (135 km², V2924020) is now closed (last records in 1997). The gauging station located at St-Rambert-en-Bugey (232 km², V2924010) is recording river flow on a perennial section. Flow intermittence is observed at the gauging station located at Saint-Denis-en-Bugey (288 km², V2934010). Discharges available for this stations in the French database HYDRO are not reliable before 1981 (zero values have been probably replaced by "not available" data). Records before 1981 were discarded from the statistical analysis.

Flow/aquatic state observations (e.g. "flow", "disconnected pools" and "dry bed"): One site of the ONDE network is located at Bettant (http://onde.eaufrance.fr/acces-aux-donnees/station/V2934011) along the river network between St-Rambert-en-Bugey and Saint-Denis-en-Bugey. Once a month the section is visually inspected between April and October since 2012 and one of the statuses is assigned at each observation among "visible flow", "no visible flow" and "dried out".

Effect of intermittence on invertebrates

Relationships between benthic and hyporheic density, taxonomic richness and hydrological metrics have been investigated along the Albarine River basin (Datry, 2012). Benthic and hyporheic samples were collected from 18 sites along the entire temporary reach in spring, just before the beginning of summer dry events and in autumn, at least three weeks after flow resumption and from eleven sites located in the upstream perennial reach. Dry events have been reconstructed at the downstream sites using ELDMOD (Rupp *et al*., 2008). Results have shown that benthic and hyporheic density decreased exponentially and linearly, respectively, with increased duration of no-flow events.



Datry T. (2012). Benthic and hyporheic invertebrate assemblages along a flow intermittence gradient: effects of duration of dry events. Freshwater Biology, 57(3), 563-574.

Rupp *et al*. (2008). Reconstruction of a daily flow record along a hydrologically complex alluvial river. Journal of Hydrology, 359, 88–104.

Author(s): Eric Sauquet (eric.sauquet@inrae.fr)

6. Lauze (FRANCE)

Gascony tributary of the Garonne River basin

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Lauze at Sémézies-Cachan (Faget-Abbatial)
Coordinates (°): 43.4989, 0.73095 (WSGS84)
Catchment area (km²): 36
Characteristic channel width: ☐ <1 m ☐1-5 m ☐ >5 m ☒Unknown
River length (km): 17.8
Elevation range (m a.s.l.): 191 to 343

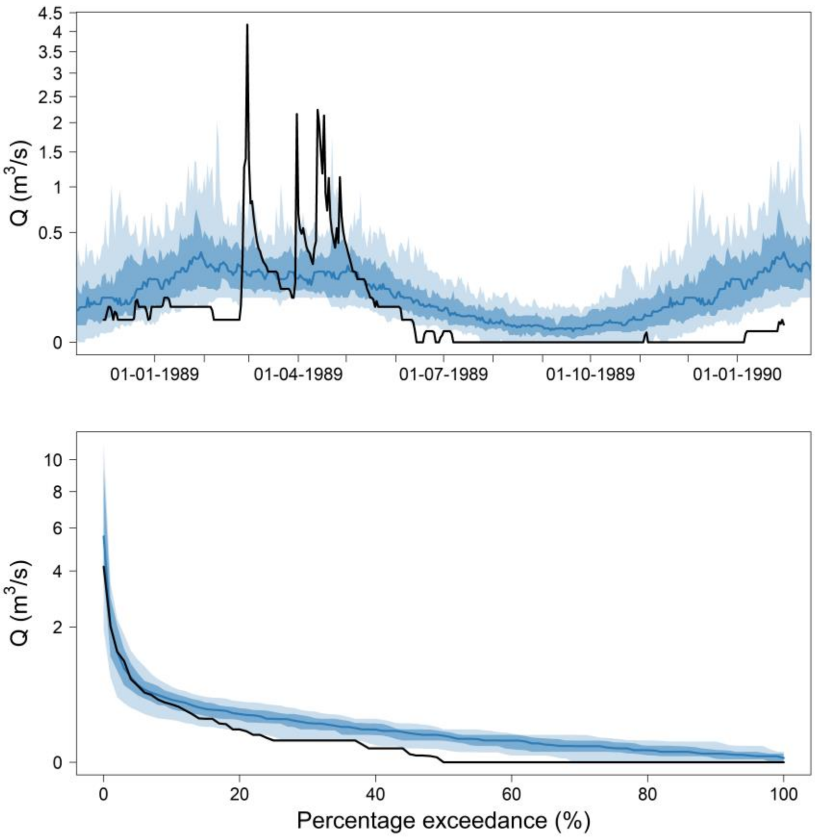
Geology: ☐ Calcareous (limestone, chalk) ☒Silicate (clay, granite)
☐Unknown ☐Other:

Climate:
Mean annual precipitation (mm/year): 730
Mean annual temperature (°C): 12.2
Köppen class: Temperate oceanic climate (Cfb)

Land use (forest and natural, agricultural, wetlands, artificial): Agriculture (78%), forest (22%) (source: Corine Land Cover 2006)

Artificial influence: No regulation, abstraction for irrigation purposes (minor influence on river flow regime, source: www.bnpe.eaufrance.fr)

The Sémézies-Cachan gauging station (© Compagnie d'Aménagement des Côteaux de Gascogne, www.cacg.fr)



Hydrographs and flow duration curves of the Lauze at Sémézies-Cachan (1965-2015) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Flow metrics (1965-2015)

MAF (m^3/s):	0.21
M_{AMD} (day):	23
CV_{AMD} (day):	1.84
$\tau 0$:	3 August
$\tau 0_r$:	0.75
k:	0.82
M_{AN} (day):	31
CV_{AN} (day):	1.70

Description and reasons for intermittence

River flow intermittence is naturally expected in Gascony due to impervious substratum (clay). During the 19th century, the Neste Canal was built and flows from the Neste River basin are now partly diverted to regulate and to moderate low flows and to supply water for irrigation purposes in Gascony (Villocel, 2002). The canal system grew progressively until now and the Lauze River basin is one of the Gascony basins still experiencing zero-flow events.

Spatial pattern: Intermittent in the headwaters and in the middle part of the catchment

Seasonality: Zero flows are not observed every year but they did occur regularly in late summer and fall during moderate to severe hydrological droughts.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☐Interaction with groundwater ☐ Other:

Villocel A. (2002). The “Neste System”: a fresh “citizen approach” to water resource management. La Houille Blanche, 4-5, 78-82.

Observations of intermittence

Gauging station(s): Only one gauging station measures discharges of the Lauze River basin at Sémézies-Cachan (http://www.hydro.eaufrance.fr/). This station (O2725010) is one of the 236 gauging stations with at least 40 years of daily flows, with measurements deemed to be of high quality and no significant influence in low flows used to analyse trends in low flow statistics in France (Giuntoli *et al.*, 2013).

Flow/aquatic state observations (e.g. “flow”, “disconnected pools”, “dry bed”): One site of the ONDE network (http://onde.eaufrance.fr) is located at Meilhan upstream to the Sémézies-Cachan gauging station. Once a month the section is visually inspected between May and October since 2012 and one of the states is assigned at each observation among “visible flow”(■■), “no visible flow” (■) and “dried out” (■).

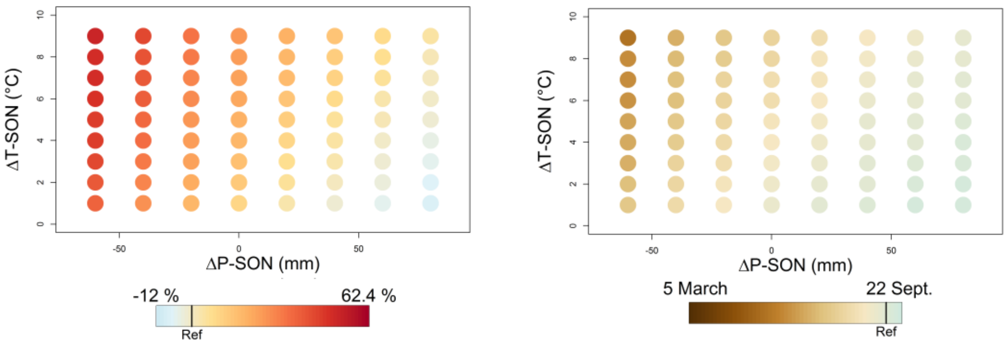
Year	May	June	July	August	September	October
2011						
2012						
2013						
2014						
2015						
2016						
2017						
2018						

Flow-state observations of the Lauze River at Meilhan
(source: http://onde.eaufrance.fr/acces-aux-donnees/station/O2720001)

Giuntoli *et al*. (2013). Low flows in France and their relationship to large-scale climate indices. Journal of Hydrology, 482, 105-118, doi: 10.1016/j.jhydrol.2012.12.038

Sensitivity of flow intermittence to climate change

Following (Prudhomme *et al*., 2015) the sensitivity of the flow intermittence to climatic changes was examined for the Lauze River basin. Perturbed climate conditions were generated applying incremental changes to historical data. They were introduced as inputs in the rainfall-runoff model GR5J to derive timing and severity of zero-flow events under modified climates. Results are presented using a two-dimensional response surface (left: change in proportion of zero flows, right: mean date of the first day with zero flow), with axes represented by the main climate factors influencing flow intermittence (here changes in mean precipitation and temperature from September to November).



Prudhomme C., Sauquet E., Watts G. (2015). Low flow response surfaces for drought decision support: a case study from the UK. Journal of Extreme Events, 2(2). doi: 10.1142/S2345737615500050

Author(s): Eric Sauquet (eric.sauquet@inrae.fr)

7. Lirou (FRANCE)

French Mediterranean basin

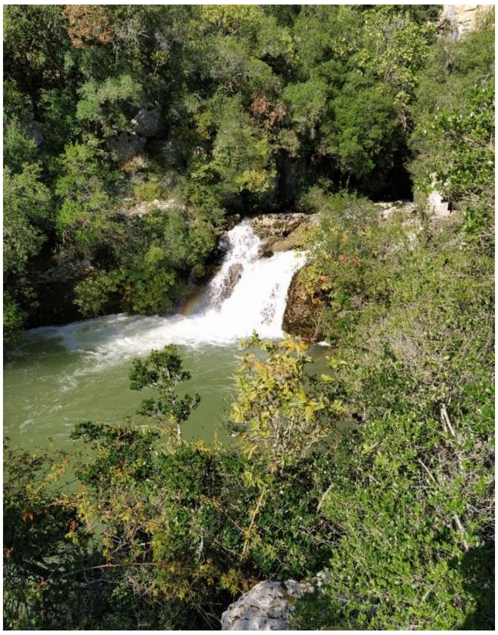
Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Lirou at Le Triadou (Y3205010)
Coordinates (°): 43.729, 3.867 (WGS84)
Catchment area (km²): 84.2
Characteristic channel width: ☐ <1 m ☒1-5 m ☐ >5 m ☐Unknown
River length (km): ≈ 10.7
Elevation range (m a.s.l.): 66 to 115

Geology: ☒ Calcareous (limestone, chalk) ☐ Silicate (clay, granite) ☐ Unknown ☐ Other: micaschists, amphibolites, phyllades and gneiss.

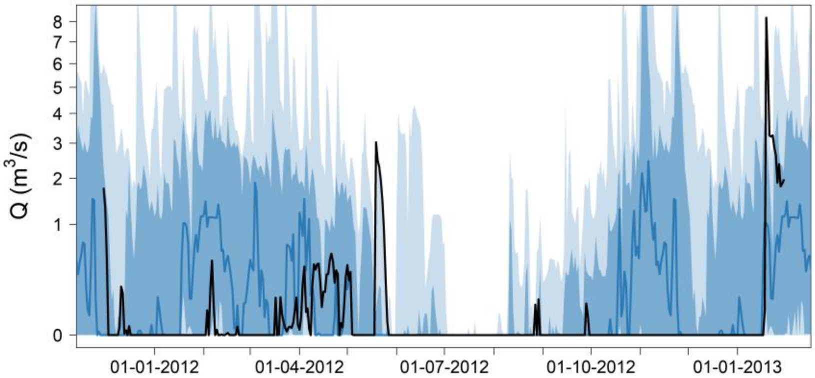
Climate:
Mean annual precipitation (mm/year): 960
Mean annual temperature (°C): 13.4
Köppen class: Hot-summer Mediterranean climate (Csa)

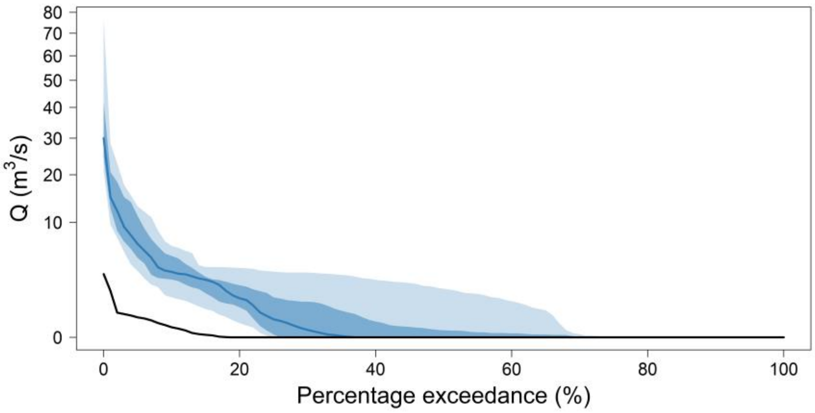
Land use (forest and natural; agricultural; wetlands; artificial): Forest (62%), agriculture (30%), urban (8%) (source: Corine Land Cover 2018)

Influence: There are no major dams upstream. Yet, the river flow regime may be influenced by water management rules applied to the Lez spring and by water losses occurring between the spring and the gauging station



View over the flowing Lirou spring after a rainfall event (Feb. 2020). Site: Les Matelles, France (photo: V. Taver)





Hydrographs and flow duration curves of the Lirou at Le Triadou (Y3205010) (2008-2019) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

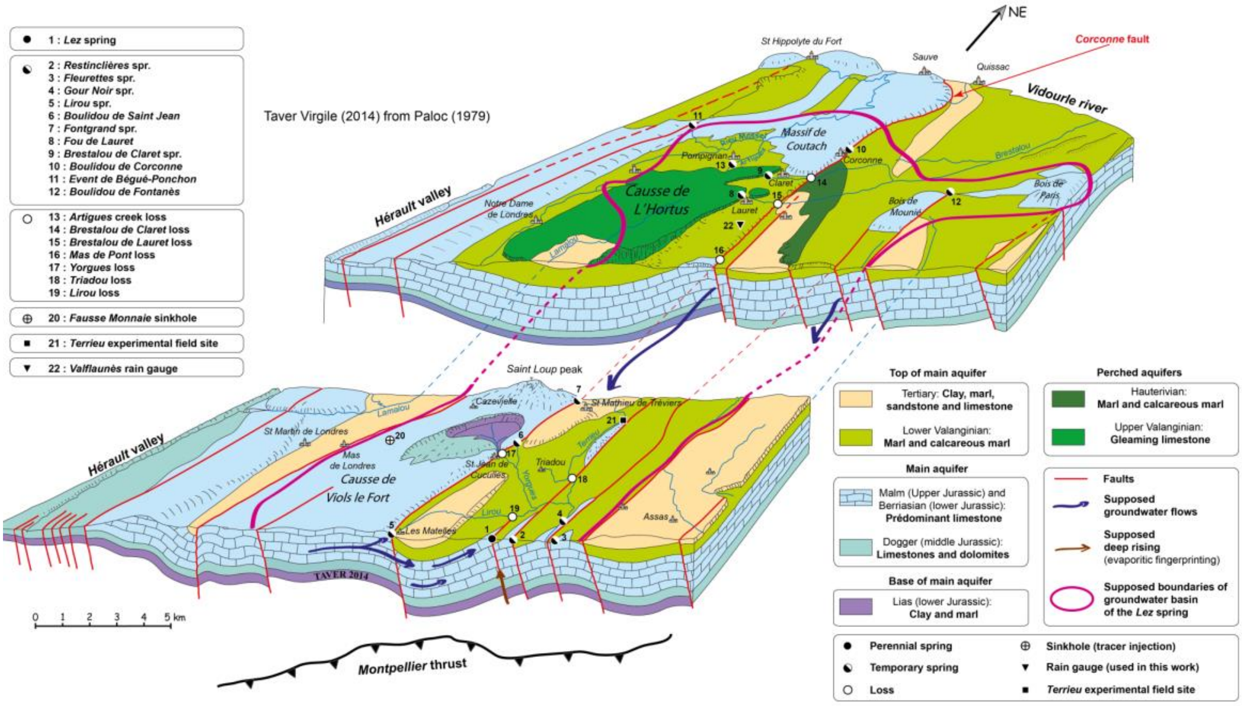
Flow metrics (2008-2019)

MAF (m³/s):	1.5
M_{AMD} (day):	77
CV_{AMD} (day):	0.45
$\tau 0$:	9 January
$\tau 0_r$:	0.66
k:	0.72
M_{AN} (day):	206
CV_{AN} (day):	0.46

Description and reasons for intermittence

Flow intermittence observed in the headwaters of the Lirou River basin stems from the nature of the Lirou spring: this is an overflow spring of a karst aquifer (Lez aquifer) that flows over carbonate rocks. Overflow occurs when water levels within the Lez aquifer system are sufficiently high to feed the Lirou spring located upstream the main karst spring (Lez).

Spatial pattern: The drainage area of the Lez aquifer is made up of discontinuous limestone outcrops linked together by subsurface circulation. River losses mainly occur at the contact between over limestone terrains and faults.



Interpretative diagram of the hydrogeological basin of the Lez spring (Taver, 2014 modified from Paloc, 1979)

Seasonality: High water levels conditions are met (i) after the fall season when recharge was sufficient to recover from the low water levels reached at the end of the summer time period and (ii) after extreme rainfall events, which occur during the fall season. Thus, thanks to fast pressure transfers within the karst aquifer system, the Lirou spring functioning may be seen as "discharge bursts": discharge peaks reach high flow rates (up to 40 m^3s^{-1}) in very short time (hours) and discharge tails may end shortly after the peak discharge (within days) due to water infiltration through "losses" along the riverbed.

Driver(s): ☐ Summer dry period ☐Freezing/snow ☒Water management
☒Interaction with groundwater ☐ Other:

Ladouche *et al*. (2014). Semi-distributed lumped model of a karst system under active management. Journal of Hydrology, 509, 215-230. https://doi.org/10.1016/j.jhydrol.2013.11.017

Paloc, H. (1979). Alimentation en eau de la ville de Montpellier. Localisation d'un emplacement de captage dans le réseau souterrain de la source du Lez. Détermination de ses principales caractéristiques en préalable à l'exécution des travaux. Tech. Rep. BRGM 79-SGN-654-LRO.

Taver, V. (2014). Caractérisation et modélisation hydrodynamique des karsts par réseaux de neurones. Application à l'hydrodystèmes du Lez. Thesis, Ecole des Mines d'Alès, 202 pp.

Observations of intermittence

Gauging station(s): There are five gauging stations in the Lez River basin (http://www.hydro.eaufrance.fr/). Flow intermittence is only observed at the gauging station Le Triadou.

Flow/aquatic state observations (e.g. "flow", "disconnected pools" and "dry bed"): One site of the ONDE network is located at Prades-le-Lez (http://onde.eaufrance.fr/acces-aux-donnees/station/Y3200031) downstream of Le Triadou. Once a month the section is visually inspected between April and October since 2012 and one of the statuses is assigned at each observation among "visible flow", "no visible flow" and "dried out". The dominant class is "dried out" (30% of observations).

Author(s): Vivien Hakoun (v.hakoun@brgm.fr)

8. Réal Collobrier (FRANCE)

French Mediterranean basin

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Réal Collobrier at Pont de Fer (Y4615610)
Coordinates (°): 43.236, 6.219 (WGS84)
Catchment area (km²): 70.4
Characteristic channel width: ☐ <1 m ☒1-5 m ☐ >5 m ☐Unknown
River length (km): ≈ 16
Elevation range (m a.s.l.): 70 to 780

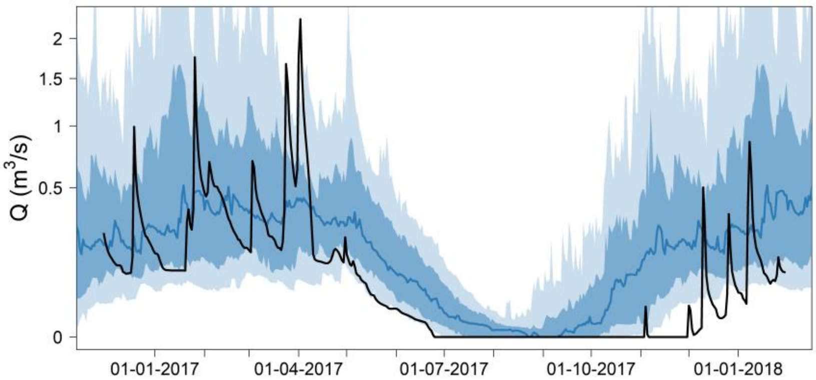
Geology: ☐ Calcareous (limestone, chalk) ☐ Silicate (clay, granite)
☐ Unknown ☒ Other: Micaschists, amphibolites, phyllades and gneiss

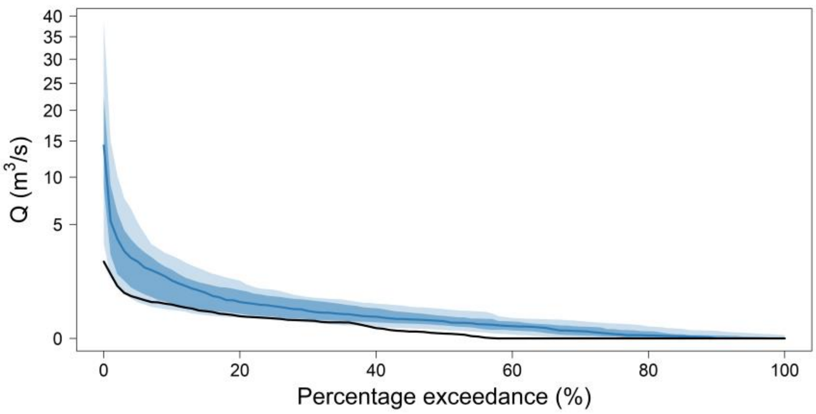
Climate:
Mean annual precipitation (mm/year): 1050
Mean annual temperature (°C): 14
Köppen class: Hot-summer Mediterranean climate (Csa)

Land use (forest and natural; agricultural; wetlands; artificial): Forest (83%), agriculture (15%), urban (2%) (source: Corine Land Cover 2018)

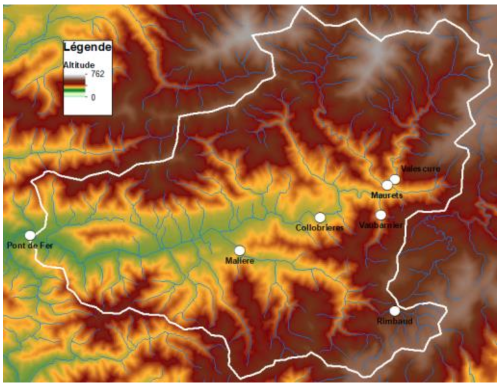
Influence: No regulation

Dry bed observed in September 2017 © Irstea





Hydrographs and flow duration curves of the Réal Collobrier River at Pont de Fer (Y4615610) (1966-2019) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale



The Real Collobrier basin and the sub-basins defined by the seven gauging stations available on the catchment

Flow metrics (1966-2019)

MAF (m³/s):	0.58
M_{AMD} (day):	47
CV_{AMD} (day):	0.87
$\tau 0$:	28 July
$\tau 0_r$:	0.84
k:	0.8(
M_{AN} (day):	55
CV_{AN} (day):	0.83

Description and reasons for intermittence

The Réal Collobrier hydrological observatory in southeastern France, managed by Irstea since 1966, constitutes a benchmark site for regional hydro-climatology. Because of the dense network of stream gauges and rain gauges available, this site provides a unique opportunity to evaluate long-term hydro-meteorological Mediterranean trends. The main catchment (70 km²) and its sub-catchments are located in the Maures massif of southeastern France, close to the Mediterranean coast. The vegetation is composed of forest mainly calcified on crystalline soils (maquis of heath, cork oak, maritime pine and chestnut). Direct human influence has been negligible over the past 50 years. The land use / land cover has remained almost unchanged, with the notable exception of a wildfire in 1990 that affected a small sub-catchment. Therefore, changes in the hydrological response of the catchments are caused by changes in climate and/or physical conditions. The analysis of 50-year daily series of precipitation and streamflow shows that there is a marked tendency towards a decrease in the water resources of the Réal Collobrier catchment in response to climate trends, with a consistent increase in drought severity and duration. However, the significance of the changes varies across the sub-catchments (Folton *et al*., 2019).

Spatial pattern: Intermittence depend on location and geological structure of sub-basins.

Seasonality: Flow ceases in summer.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☒Interaction with groundwater ☐ Other:

Folton *et al*. (2019). A 50-year analysis of hydrological trends and processes in a Mediterranean catchment. Hydrology and Earth System Sciences, 23, 2699–2714. https://doi.org/10.5194/hess-23-2699-2019

Observations of intermittence

Gauging station(s): There are seven gauging stations in the Réal Collobrier River basin. At the outlet, at the Pont de Fer gauging station (70.4 km²) the intermittence can last from a few days to a few months depending on the year. It is very variable for all sub-basins. The Rimbaud River basin (1.5 km²) has the strongest intermittence because of its low water storage capacity. Its intermittence is strongly correlated with the intermittence of the rainfall of the Mediterranean climate. Conversely, the Vaubarnier River basin (1.5 km²) shows no intermittence because of its large water storage capacity related to a particular geology of heavily fractured rocks. In the other gauged basins, intermittence is variable and depends on the characteristics of the summer period.

Flow/aquatic state observations (e.g. “flow”, “disconnected pools” and “dry bed”): No information on aquatic states is available.

Author(s): Patrick Arnaud (patrick.arnaud@inrae.fr)

9. Evrotas (GREECE)

East Peloponnese Water District

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Evrotas at Vrontamas
Coordinates (°): 36.976522, 22.580075 (WGS84)
Catchment area (km²): 2420
Characteristic channel width: ☐ <1 m ☐1-5 m ☒ >5 m ☐Unknown
River length (km): 5143 (total river network)
Elevation range (m a.s.l.): 41.1% of the area > 600 m; 46.2% 150-600 m; 12.7% 0 -150 m

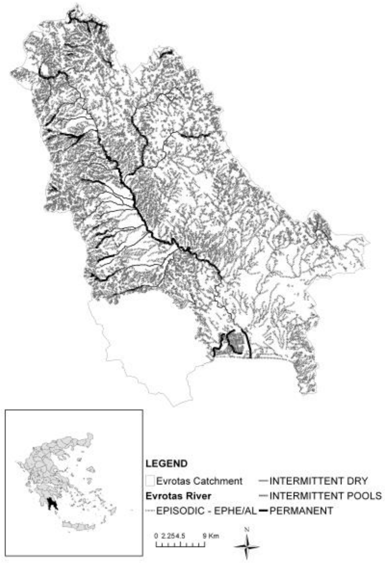
Geology: ☒ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☐Other:

Climate:
Mean annual precipitation (mm/year): 932
Mean annual temperature (°C): 16
Köppen class: Hot-summer Mediterranean climate (Csa)

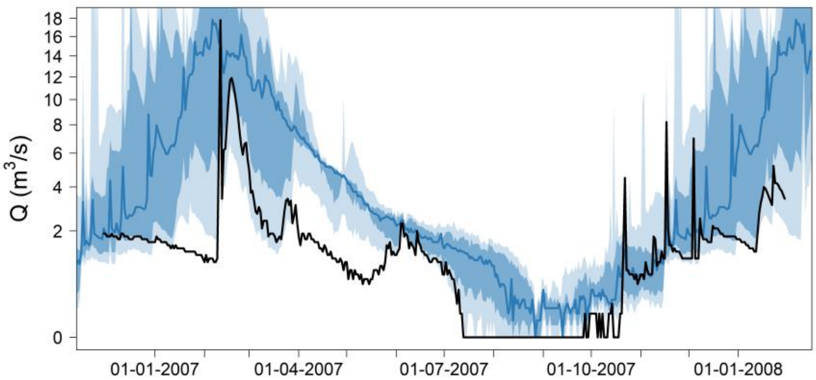
Land use (forest and natural, agricultural, wetlands, artificial): Forest/grassland/bareland (61.3%), agricultural (orange trees, olive trees, cereals, vineyards and vegetables) (38%), urban land (0.7%)

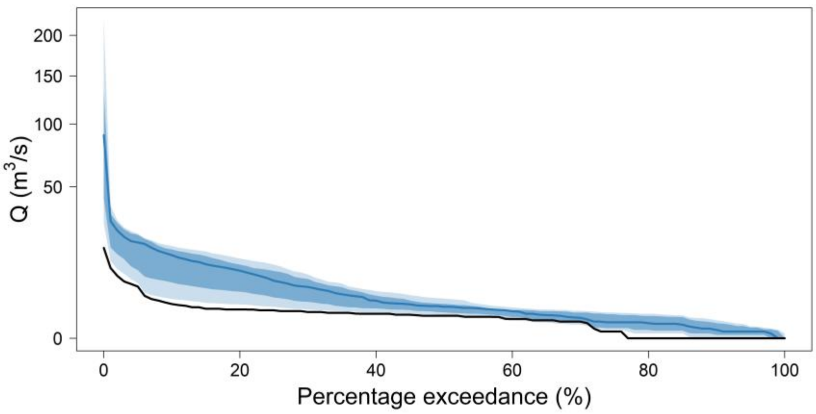
Artificial influence: Irrigation

Photo: Mike J. Kirkby; date: 03/2009



Map showing the Evrotas river network of permanent flow, intermittent flow (dry river bed or sustain pools during the no-rain period) and of ephemeral/episodic flow





Hydrographs and flow duration curves of the Evrotas at Vrontamas (2005-2010) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Flow metrics (2005-2010)

MAF (m^3/s):	5.02
M_{AMD} (day):	19
CV_{AMD} (day):	1.63
τ:	7 August
τ_r:	0.94
k:	0.94
M_{AN} (day):	26
CV_{AN} (day):	1.38

Description and reasons for intermittence

The Evrotas basin (River ID GR33), on the south-east peninsula of the Peloponnese in Greece, has a river network including temporary and permanently flowing tributaries and reaches with the main river running from north to south between the Taygetos and Parnonas Mountains (max height: 2400 m). Evrotas is a predominantly rural river basin with intensive water quantity and quality problems resulting in over utilization of the river water and intense pollution problems. Surface and groundwater abstraction for irrigation contributes to the gradually flow reduction in parts of the main stream (irrigation rate of 0.9 m/m² compared to the recommended value of 0.5 m/m² annually). The river basin has numerous water supply and irrigation wells for public use (more than 100) in addition to 3000 private wells.

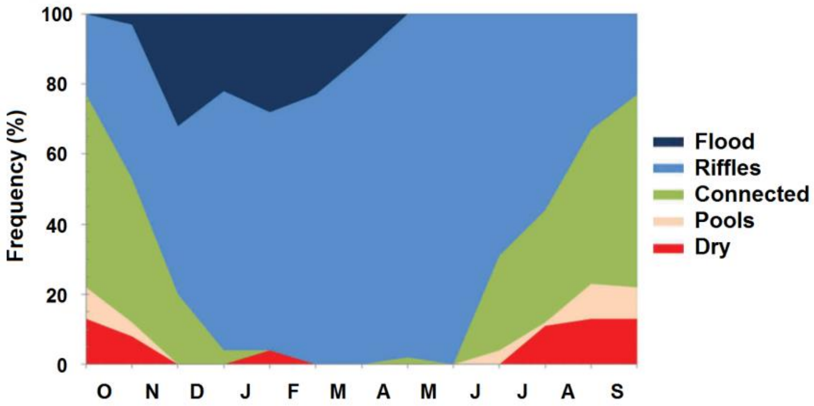
Spatial pattern: Despite the high storage capacity of karst Parnonas and the area that covers (434 km², 18% of the basin), streams in that part of the basin experience only ephemeral flow. The water storage of Taygetos mountain (Vivari (mean annual outflow 390 mm/yr, 110 km²), Skortsinos (390 mm/yr, 16 km²) and Taygetos karst (480 mm/yr, 271 km²)) cover important drinking water and irrigation demands of the basin (Tzoraki *et al*., 2011). The operation of numerous private and domestic wells operate in that part of the basin and the direct abstraction from the river during the irrigation period shifts high parts of the river from permanent to intermittent flow.

Seasonality: The stream can be dry for as much as 20% of the time, especially between July and November. Pools occur mainly in autumn. From November to July the riverbed contains flowing water. The flood phase occurs about 5-10% of the time from December to April (Querner *et al*., 2016).

Querner *et al*. (2016). Simulating streamflow variability and aquatic states in temporary streams using a coupled groundwater-surface water model. Hydrological Sciences Journal, 61(1), 146–161.

Tzoraki *et al*. (2011). Hydrological modeling of an intense carstified river system. N. Lambrakis *et al*. (Eds.). Advances in the Research of Aquatic Environment, 1, 179-186. doi 10.1007/978-3-642-19902-8

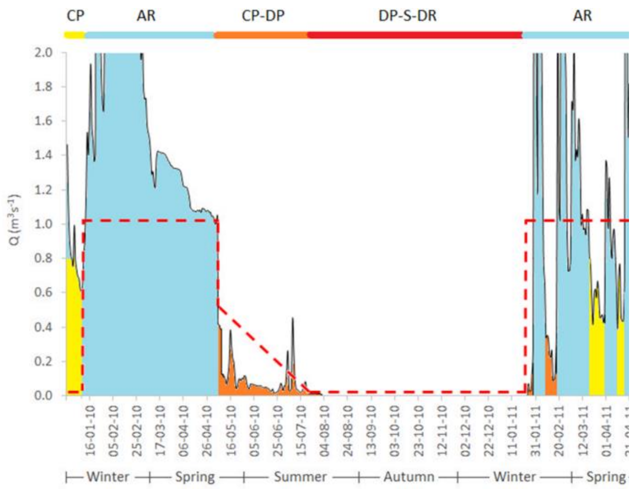
Driver(s): ☒ Summer dry period ☐Freezing/snow ☒Water management
☐Interaction with groundwater ☐ Other:



Frequency of the considered flow phases for the Vrontamas gauge derived from measured data (Querner et al., 2016)


Karstic springs in Taygetos mountains

Environmental flow assessment



Temporal pattern of aquatic states and environmental flow regime of one reach in the Evrotas River main channel (analysis based on the integration of the hydrodynamic-habitat and hydrological data, after (Skoulikidis *et al*., 2018)) - Symbols: AR abundant riffles, CP connected pools, DP disconnected pools, CPDP transition between CP and DP, DP-S-DR transition between DP, and the dry states (subsurface-flow and dry). The flood-flows state is included in AR. Dotted lines highlight the annual environmental flow regime.

Skoulikidis *et al*. (2019). Conceptualization and pilot application of a model-based environmental flow assessment adapted for intermittent rivers. Aquatic Sciences, 81-100.

Author(s): Rania Tzoraki (rania.tzoraki@aegean.gr)

10. Celone (ITALY)

Apulia Region, tributary of the Candelaro

Characteristics from the catchment at: ☒ the outlet
☐ the gauging station:
Coordinates: 41.4030, 15.3646 (WGS84)
Catchment area (km²): 317
Characteristic channel width: ☐ <1 m ☐ 1-5 m ☒ >5 m ☐ Unknown
River length (km): 63
Elevation range (m a.s.l.): 1150 to 0

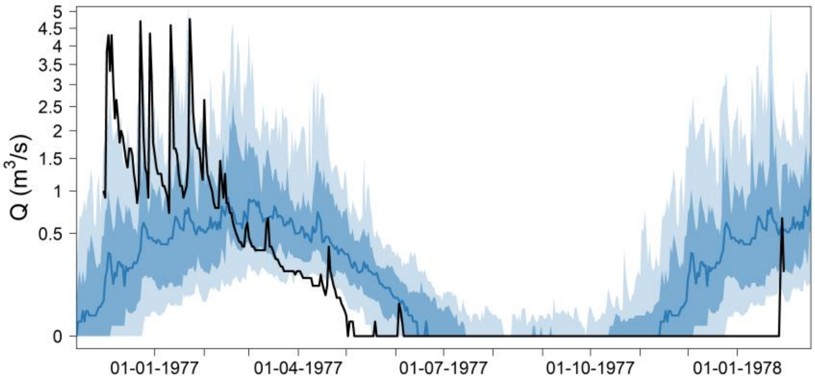
Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒Other: Sedimentary

River reach in alluvial plain. Dry phase, 16/09/2010. 41°20'04.76''N; 15°12'04.79E

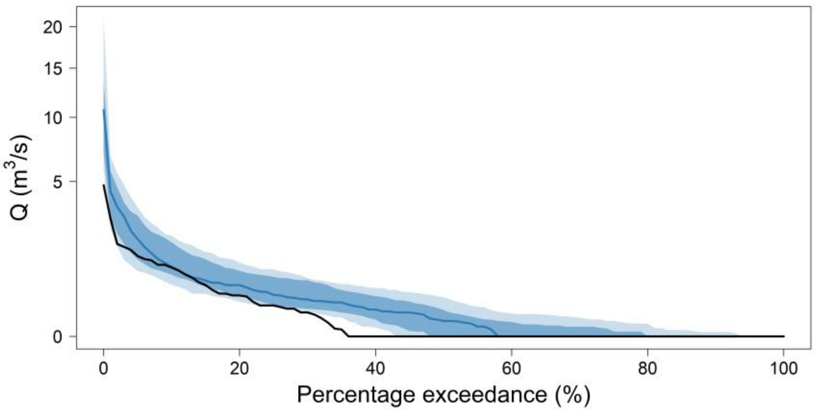
Climate:
Mean annual precipitation (mm/year): 625
Mean annual temperature (°C): 16
Köppen class: Humid subtropical climate (Cfa)

Land use (forest and natural, agricultural, wetlands, artificial): Cereals (70%), olive trees (4%), forest (8%), natural areas and pasture (4%), vegetables (9%), vineyard (3%), others (1%), urban areas (1%)

Artificial influence: Minimal upstream, heavily downstream (dam)



River reach in the hilly area. Flowing phase, May 2009. 41°20'16.28''N; 15°11'25.02E



Hydrographs and flow duration curves of the Celone at S. Vincenzo (1965-1996) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Flow metrics (1965-1996)

MAF (m^3/s): 0.49

M_{AMD} (day): 108
CV_{AMD} (day): 0.61
$\tau 0$: 8 June
$\tau 0_r$: 0.69
k: 0.81
M_{AN} (day): 138
CV_{AN} (day): 0.48

Description and reasons for intermittence

The natural flow regime of the Celone River basin is characterized by a high intra- and inter-annual variability. Due to the high variability in time and space of rainfall events, extreme variations in flow and flash floods are very common, especially in summer. The hydrograph (at S. Vincenzo gauging station, see Figure in first page) shows a very rapid rising stage and a short lag time (time between peak rainfall and peak discharge).

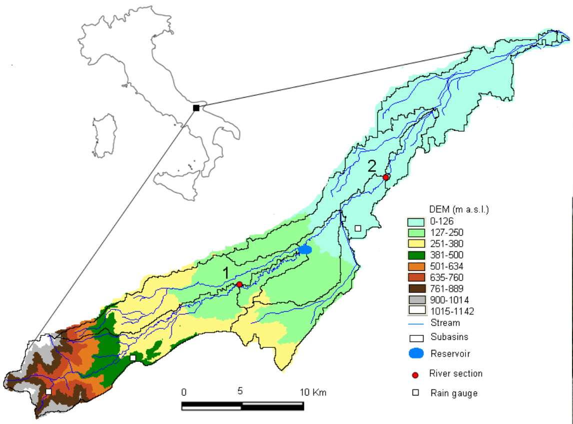
Spatial pattern: Most of the headwaters are perennials. The medium course is dry almost every year. Downstream the reservoir the flow regime is ephemeral.

Seasonality: From June to December, a long period of extreme low flow with a reduction of flow into isolated pools is generally observed along the course of the river. The absence of flow is generally recorded in summer, but often it occurs also in autumn and winter.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☐Interaction with groundwater ☐ Other:

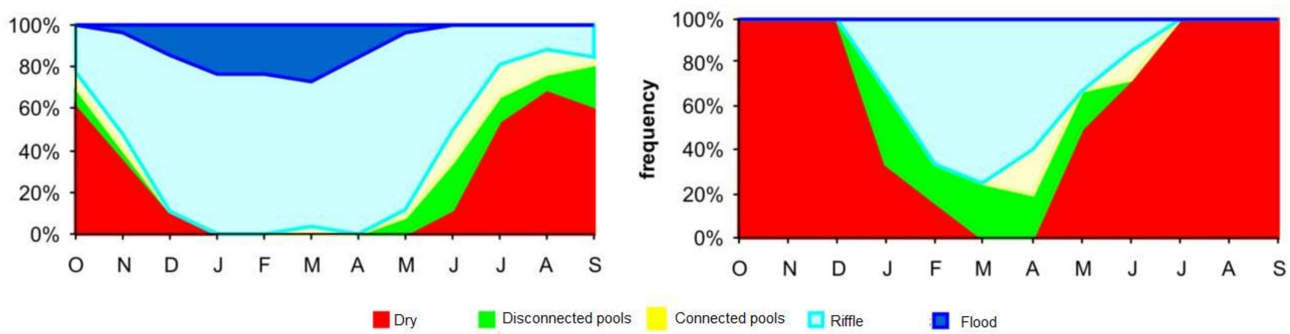
Observations of intermittence

Gauging station(s): Two gauging stations are equipped along the main course, upstream and downstream the reservoir, respectively.



Gauging station 2 (Celone at Ponte Foggia); 15.521356E; 41.490992N

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): The patterns of occurrence of aquatic states (ASs) has been evaluated near the gauging stations 1 and 2. The flow thresholds between one class to another have been fixed on flow duration curves and field measurements. At the gauging station 1, a high frequency of dry phase and disconnected pools has been recorded from July to November, whilst from January to April the reach goes through high flow conditions, whereas from May to December flow condition varies from year to year. For reaches downstream the dam, the dry conditions are recorded from July to December and continuous flow is generally recorded from February to April.



Frequency of occurrence of Aquatic States recorded at gauging station 1 (left) and gauging station 2 (right)

Author(s): Anna Maria De Girolamo (annamaria.degirolamo@ba.irsa.cnr.it)

11. Rio Mulargia (ITALY)

Sardinia Region

Characteristics from the catchment at: the outlet ☐
☒ the gauging station: upstream the reservoir
Coordinates: 39.6417, 9.1947 (WGS84)
Catchment area (km²): 65
Characteristic channel width: ☐ <1 m ☐ 1-5 m ☒ >5 m ☐ Unknown
River length (km): 44
Elevation range (m a.s.l.): 750 to 250

Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite) ☐Unknown ☐Other: Sedimentary

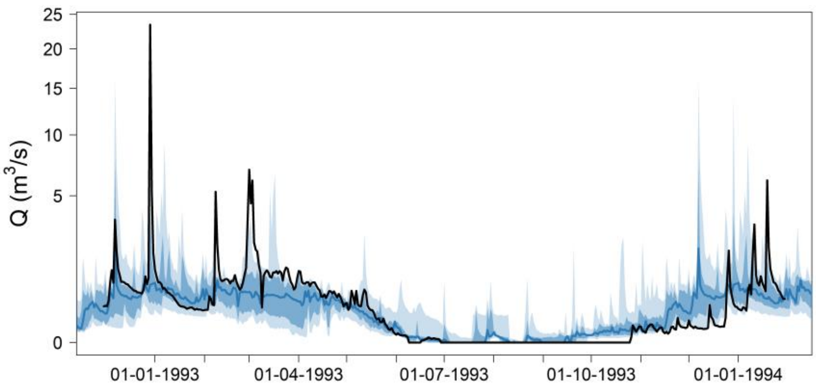
Climate:
Mean annual precipitation (mm/year): 530
Mean annual temperature (°C): 10
Köppen class: Hot summer Mediterranean climate (Csa)

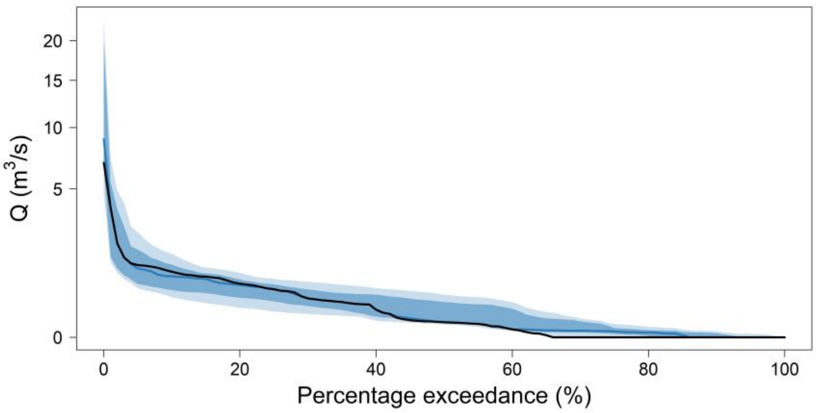
Land use (forest and natural, agricultural, wetlands, artificial): Winter pasture (40%), range-grasses (4.8%), forest (0.2%), natural areas and pasture (34%), range brush (21%)

Artificial influence: Minimal upstream the dam

River reach near the outlet (Mulargia reservoir). 22/08/2004. Photo: M. Cazzola; coordinates: 39°38'34.78"N, 9°11'27.98"E

River reach upstream the reservoir. Flowing phase. Photo: A. Zoppini; coordinates: 39°38'31N, 9°11'40E





Hydrographs and flow duration curves of the Mulargia station upstream the reservoir (1992-1998) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Flow metrics (1992-1998)

MAF (m^3/s):	0.42
M_{AMD} (day):	39
CV_{AMD} (day):	0.97
$\tau 0$:	10 June
$\tau 0_r$:	0.72
k:	0.84
M_{AN} (day):	60
CV_{AN} (day):	0.77

Description and reasons for intermittence

The natural flow regime of the Mulargia River is characterized by a high intra- and inter-annual variability. Extreme variations in flow characterize the hydrograph. In summer, flash floods are very common with great impact on water quality and nutrient dynamics.

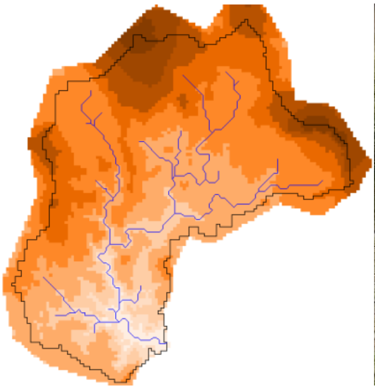
Spatial pattern: The headwater is perennial. The medium course is dry almost every year.

Seasonality: From June to December, a long period of extreme low flow with a reduction of flow into isolated pools is generally observed along the river course. The absence of flow is generally recorded in summer and in autumn.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☐Interaction with groundwater ☐ Other:

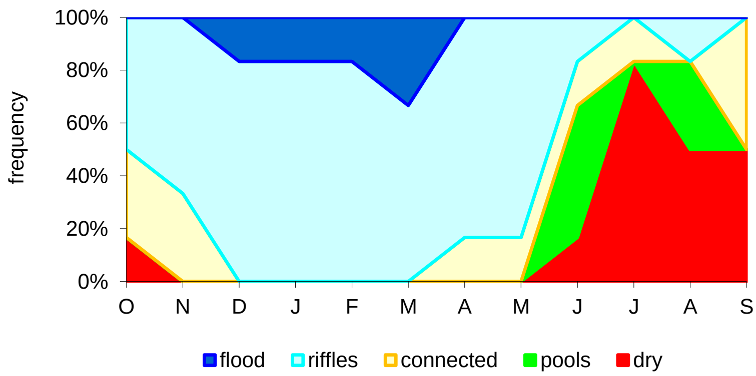
Observations of intermittence

Gauging station(s): One gauging station was equipped along the main course, upstream the reservoir (several lacks are included in the time series).



River reach near the outlet in dry season; 39°38'31N, 9°11'40E (photo: A. Zoppini)

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): The patterns of occurrence of aquatic states (ASs) has been evaluated for the river reach near the outlet. The flow thresholds between one class to another have been fixed on flow duration curves. Dry phase and disconnected pools has been recorded from May to November, whilst from December to March the reach goes through high flow conditions, whereas from May to October flow condition varies from year to year.



Frequency of occurrence of aquatic states recorded at the gauging station

Author(s): Anna Maria De Girolamo (annamaria.degirolamo@ba.irsa.cnr.it)

12. Daugyvenė (LITHUANIA)

Lielupe River Basin District

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Daugyvenė at Rimšoniai
Coordinates (°): 56.025727, 23.962106 (WGS84)
Catchment area (km²): 487.5
Characteristic channel width: ☐ <1 m ☐1-5 m ☒ >5 m ☐Unknown
River length (km): 61.1
Elevation range (m a.s.l.): 100 to 48

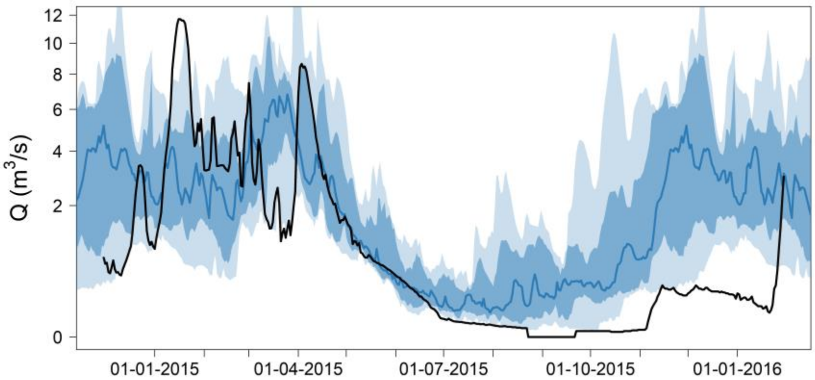
Geology: ☒ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☐Other:

Climate:
Mean annual precipitation (mm/year): >600
Mean annual temperature (°C): 6.5-7.0
Köppen class: Temperate continental climate/Humid continental climate (Dfb)

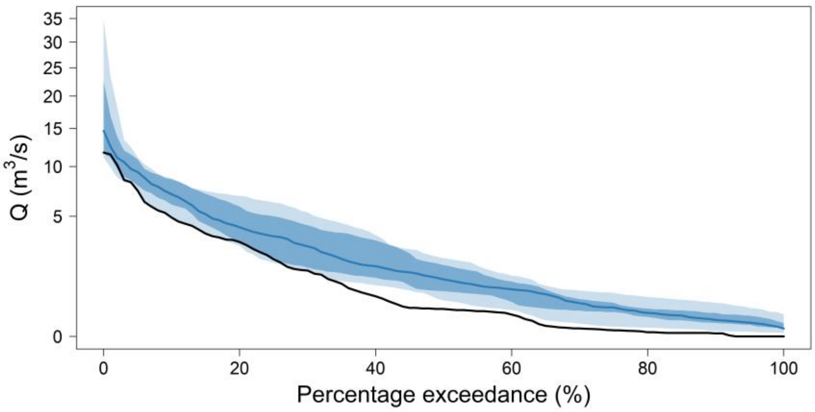
Land use (forest and natural, agricultural, wetlands, artificial): Agricultural land and natural meadows, sometimes flood meadows

Artificial influence: At headwaters - from 61.1 km (origins) to 57.0 km - the short reach of the river was canalised during the process of melioration in the middle of the last century

Dry bed observed in September 2018.
Photo: Vytautas Akstinas



Dry bed observed in September 2018.
Photo: Vytautas Akstinas



Hydrographs and flow duration curves of the Daugyvene at Rimšoniai (2006-2017) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Flow metrics (2006-2017)

MAF (m^3/s):	2.6
M_{AMD} (day):	2
CV_{AMD} (day):	3.46
$\tau0$:	24 August
$\tau0_r$:	1.00
k:	0.89
M_{AN} (day):	2
CV_{AN} (day):	3.46

Description and reasons for intermittence

The Daugyvenė River runs through the region with the lowest amount (> 600 mm) of mean annual precipitation in Lithuania.

The river is a slow-mowing because it flows through a plane lowland – therefore its watercourse slope is relatively low (0.079 %).

Spatial pattern: River is intermittent throughout its entire watercourse.

Seasonality: Intermittence occurs during very dry summers (e.g. 2015, 2018).

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☐Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): There have been two water gauging stations in the lower reaches of the Daugyvenė River: Meilūnai WGS (2.8 km from the river mouth, 484.8 km²) and Rimšoniai WGS (0.3 km from the river mouth, 487.5 km²). The former was installed in 1951 and closed in 1964, while the latter was opened in 2006 and is functioning to current day.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"):

Flow data (water level and discharge) of Lithuanian rivers are available in the annual Hydrological Yearbooks of Lithuanian Hydrometeorological Service. The measurements in WGS are carried out by automatic equipment. When the river at WGS dries out completely ("dry bed"), the Hydrological Yearbooks in the water level tables presents "Dry out". The "0" in the yearbooks means that the water in the course of the river exists, but it is impossible to measure the water discharge because it is standing.

Additional information

The climate of Lithuania is characterized by an excess of moisture therefore the rivers are usually water abundant. Flow intermittence is a rare phenomenon which is usually observed in the Middle Lithuania Lowland only during extremely dry periods in summer and autumn.

The Daugyvenė River is the right tributary of the Mūša River which is the left tributary of the Lielupė River and depends to the Lielupe River Basin District. In Lithuania, the Daugyvenė River depends to the Mūša River basin.

Author(s): Jurate Kriauciuniene (jurate.kriauciuniene@lei.lt)

13. Yslykis (LITHUANIA)

Lielupe River Basin District

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Yslykis at Kyburiai
Coordinates (°): 56.241184, 24.24431 (WGS84)
Catchment area (km²): 71.2
Characteristic channel width: ☐ <1 m ☒1-5 m ☐ >5 m ☐Unknown
River length (km): 60.7
Elevation range (m a.s.l.): 50 to 32 (Lithuanian-Latvian border)

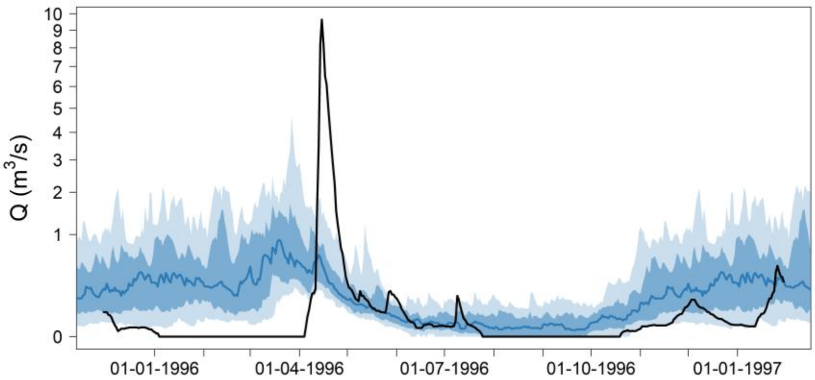
Geology: ☒ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☐Other:

Dry bed in September 2018. Photo: Vytautas Akstinas

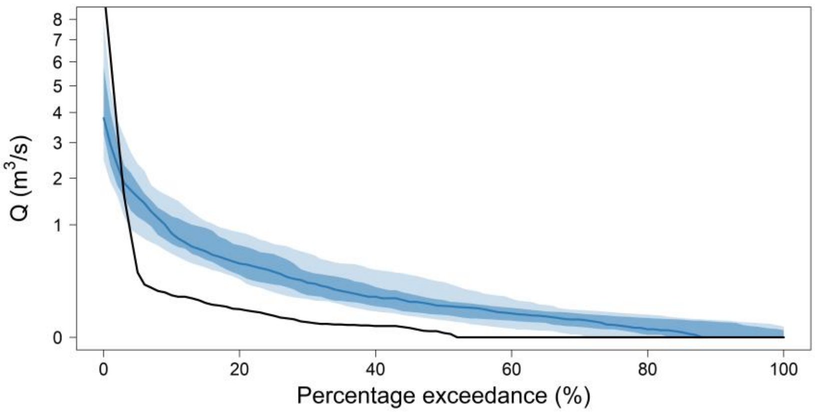
Climate:
Mean annual precipitation (mm/year): >600
Mean annual temperature (°C): 6.5-7.0
Köppen class: Temperate continental climate/Humid continental climate (Dfb)

Land use (forest and natural, agricultural, wetlands, artificial): The source of the river is a swamp surrounded by a forest however the river itself mainly flows through fertile agricultural land

Artificial influence: In 1963-1964, the river was canalised during melioration works and its riverbed was deepened at the WGS



Yslikis River in September 2018. Photo: Vytautas Akstinas



Hydrographs and flow duration curves of the Yslykis at Kyburiai (1991-2017) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Flow metrics (1991-2017)

MAF (m^3/s):	0.36
M_{AMD} (day):	41
CV_{AMD} (day):	1.09
$\tau 0$:	27 June
$\tau 0_r$:	0.59
k:	0.83
M_{AN} (day):	52
CV_{AN} (day):	1.07

Description and reasons for intermittence

The Yslykis River is the left tributary of the Lielupė River and depends to the Lielupe River Basin District. The least amount of annual precipitation in Lithuania falls on the northern part of the country, where the Yslykis River runs.

The Yslykis River flows across a loamy plain, which is fairly flat, therefore it is a slow-mowing river with a low gradient of watercourse slope (0.066 %). The river was canalised during melioration in 1963-1964. The river has small basin area.

The ground water level is low.

Spatial pattern: River is intermittent in its upper reaches which are in the territory of Lithuania. The middle and lower reaches of the Yslykis River (Islice in Latvian) are in territory of Latvia. The middle reaches of the river are rather intermittent as well.

Seasonality: The flow of the river intermits in extreme dry summers.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☐Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): There are two water gauging stations on the Yslikis River: Kyburiai WGS (46.0 km from the mouth, 71.2 km²) which is in Lithuanian territory and represents the upper reaches of the river, and Tiltsargi WGS (22 km from the mouth, 352 km²) which is in Latvian territory and represents the middle reaches of the river. Kyburiai WGS was installed in 1935 and works up to 1944; and a new gauging station was opened at the same place in 1970 and is functioning to current day. Tiltsargi WGS was opened in 1940.

The flow in both WGS´s dries completely in particularly dry periods of summer.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): Flow data of river are available in the annual Hydrological Yearbooks of Lithuanian Hydrometeorological Service. The measurements in WGS are carried out by observer and by automatic equipment, which was installed in 2009. When the river at WGS dries out completely ("dry bed"), the Hydrological Yearbooks in the water level tables presents "Dry out". The "0" means that the water exists, but it is impossible to measure the water discharge because it is standing.

Author(s): Jurate Kriauciuniene (jurate.kriauciuniene@lei.lt)

14. Brusetbekken (NORWAY)

Vest Viken

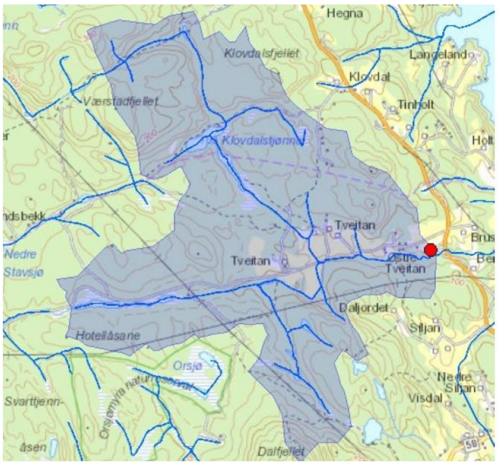
Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Brusetbekken
Coordinates (°): 59.22067, 9.3980 (WGS84)
Catchment area (km²): 7.43
Characteristic channel width: ☐ <1 m ☐1-5 m ☐ >5 m ☒Unknown
River length (km): 3.59
Elevation range (m a.s.l.): 64 to 308

Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒ Other: Gneiss covered with shallow till soils, marine clay in the lowest elevations

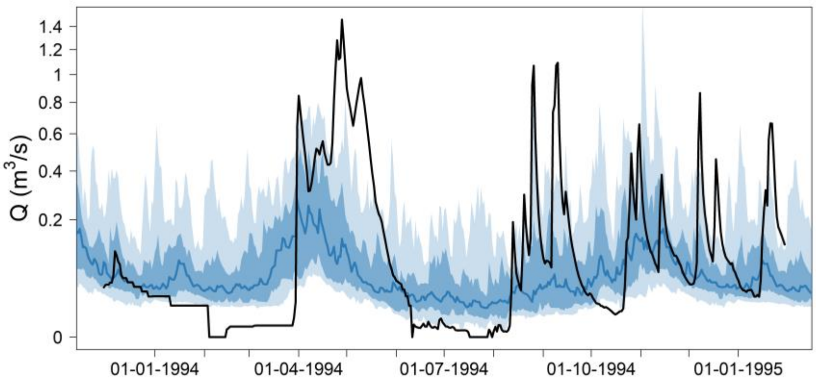
Climate:
Mean annual precipitation (mm/year): 858
Mean annual temperature (°C): 5.2
Köppen class: Warm-summer humid continental climate (Dfb)

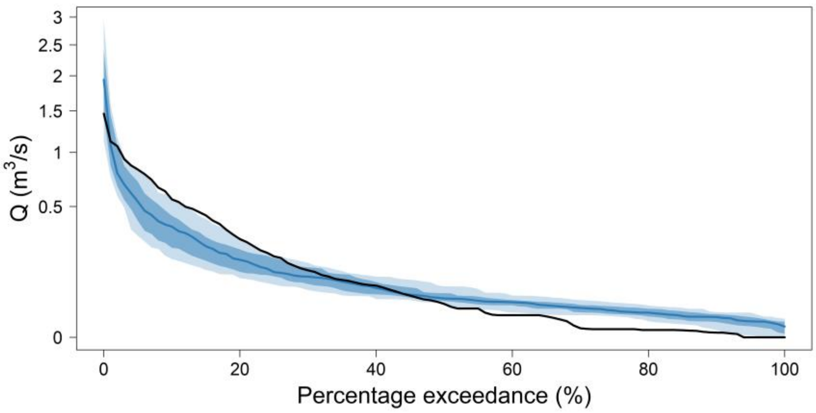
Land use (forest and natural, agricultural, wetlands, artificial): Forest (91%), agriculture (5.5%), bogs (1.7%), lakes (1.8 %)

Artificial influence: None



Map of the Brusetbekken catchment. Made in nevina.nve.no





Hydrographs and flow duration curves of the Brusetbekken at Brusetbekken (1987-2018) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Aerial photo of the small stream just upstream the gauging station. Water flowing from left to right (extracted from finn.no, map data delivered by Norkart)

Flow metrics (1987-2018)

MAF (m^3/s):	0.14
M_{AMD} (day):	4
CV_{AMD} (day):	2.13
$\tau 0$:	5 July
$\tau 0_r$:	0.10
k:	0.81
M_{AN} (day):	6
CV_{AN} (day):	2.19

Description and reasons for intermittence

The main reason for intermittence is low precipitation and high evapotranspiration. The catchment is small and there are relatively thin till soils covering the underlying bedrock that is mainly Gneiss. This catchment therefore easily dries out.

Spatial pattern: Unknown.

Seasonality: Almost all intermittent events are from the summer season. Only one event during winter 1995 that was a dry and cold winter.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☐Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): The observations are from the streamflow gauging station Brusetbekken (number 16.154.0 in the NVE database). This example of stations with intermittent streamflow was extracted from the Norwegian hydrological database hosted by NVE. The Brusetbekken gauging station is one of the available gauging stations with no influence from reservoirs, with the best quality of low flow measurements, and with the largest number of zero-flow events. The observation is based on zero flow in a sharp V-notch weir, and the zero-point of the gauging station is well established.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): No information on aquatic states is available for this small stream.

Author(s): Kolbjørn Engeland (koe@nve.no)

15. Gramstaddalen (NORWAY)

Rogaland

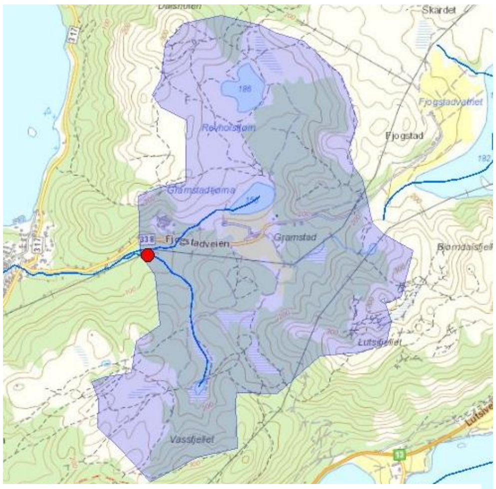
Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Gramstaddalen
Coordinates (°): 58.8814, 5.7868 (WGS84)
Catchment area (km²): 1.08
Characteristic channel width: ☐ <1 m ☐1-5 m ☐ >5 m ☒Unknown
River length (km): 0.95
Elevation range (m a.s.l.): 94 to 342.

Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒Other: Gneiss and Granite covered with shallow till soils, exposed bed rock in the highest elevations.

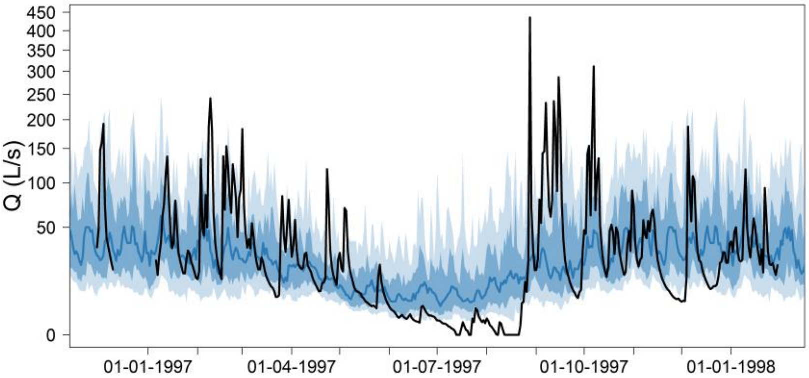
Climate:
Mean annual precipitation (mm/year): 1555
Mean annual temperature (°C): 6.8
Köppen class: Subpolar oceanic climate (Cfc)

Land use (forest and natural, agricultural, wetlands, artificial): Forest (72%), open areas above timber line (21.4%), bog (6.7%)

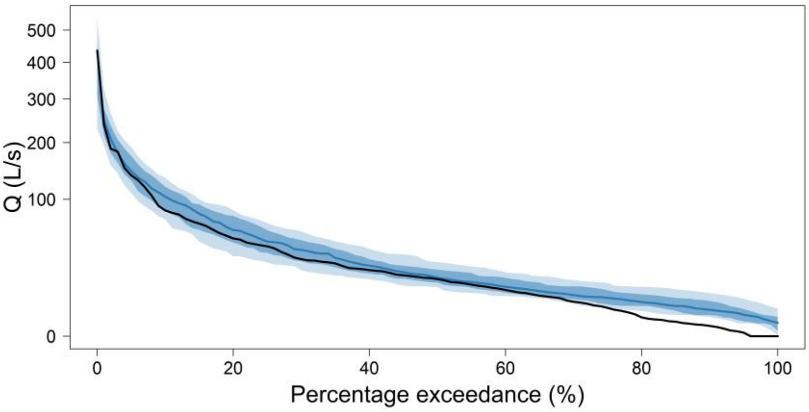
Artificial influence: None



Map of the Gramstaddalen catchment. Made in nevina.nve.no



Aerial photo of the small stream just around the gauging station. Water flowing from right to left (Extracted from finn.no, map data delivered by Norkart))



Hydrographs and flow duration curves of the Gramstaddalen at Gramstaddalen (1984-2018) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Flow metrics (1984-2018)

MAF (m^3/s):	0.04
M_{AMD} (day):	4
CV_{AMD} (day):	1.65
$\tau0$:	14 June
$\tau0_r$:	0.75
k:	0.76
M_{AN} (day):	7
CV_{AN} (day):	1.47

Description and reasons for intermittence

The main reason for intermittence is low precipitation and high evapotranspiration. The catchment is small and there are relatively thin till soils covering the underlying bedrock that is mainly Gneiss and Granite. This catchment therefore easily dries out.

Spatial pattern: Unknown.

Seasonality: Almost all intermittent events are from the summer season.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☐Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): The observations are from the streamflow gauging station Gramstaddalen (number 29.7.0 in the NVE database). This example of stations with intermittent streamflow was extracted from the Norwegian hydrological database hosted by NVE. The Gramstaddalen gauging station is one of the available gauging stations with no influence from reservoirs, with the best quality of low flow measurements, and with the largest number of zero-flow events. The observation is based on zero flow in a V-shape crump weir build in concrete, and the zero-point of the gauging station is well established.

Flow/aquatic state observations (e.g. “flow”, “disconnected pools”, “dry bed”): No information on aquatic states is available for this small stream.

Author(s): Kolbjørn Engeland (koe@nve.no)

16. Håkådalselv (NORWAY)

Møre og Romsdal

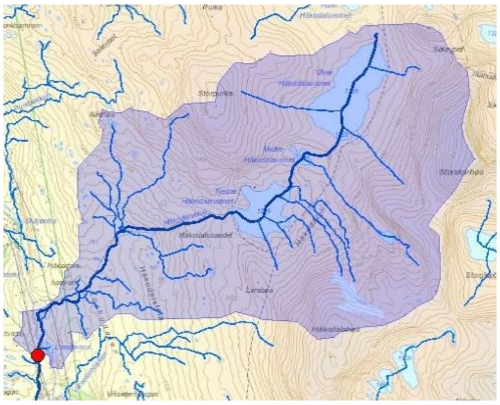
Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Håkådalselv
Coordinates (°): 62.4445, 8.6047 (WGS84)
Catchment area (km²): 23.62
Characteristic channel width: ☐ <1 m ☐1-5 m ☐ >5 m ☒Unknown
River length (km): 9.2
Elevation range (m a.s.l.): 905 to 1866

Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒ Other: Granite and Amphibolite covered with shallow till soils, more than 50% has exposed bedrock.

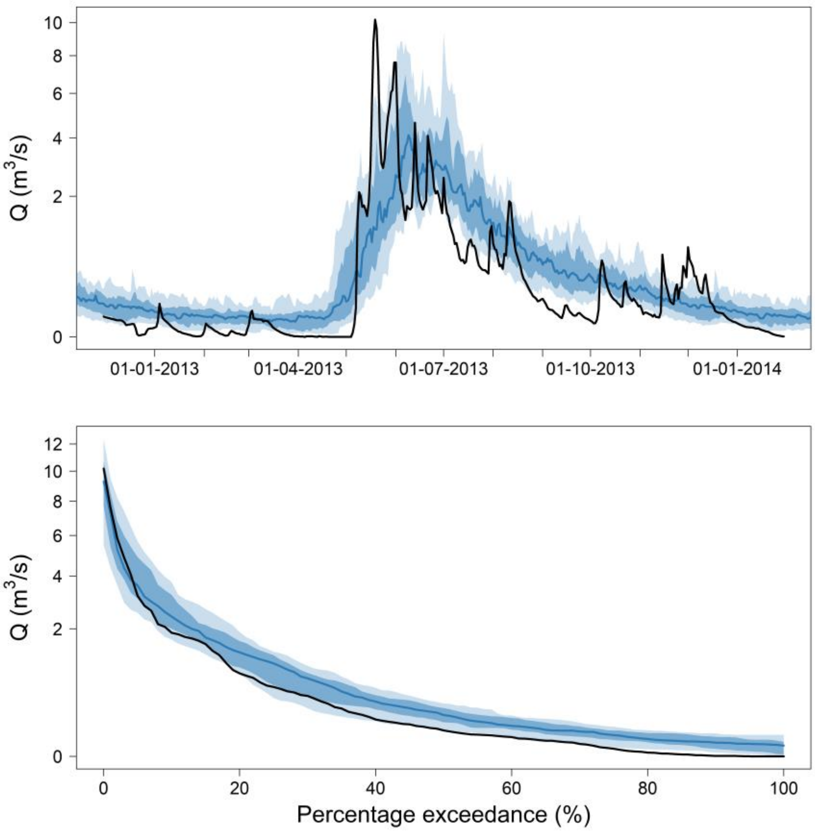
Climate:
Mean annual precipitation (mm/year): 1444
Mean annual temperature (°C): -1.9
Köppen class: Warm-summer humid continental climate (Dfb)

Land use (forest and natural, agricultural, wetlands, artificial): Open areas above timberline (96%), lakes (4.2%)

Artificial influence: None



Map of the Håkådaøseøv catchment.
Made in nevina.nve.no



Hydrographs and flow duration curves of the Håkådalselv at Håkådalselv (1987-2016) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Aerial photo of the small stream close to the gauging station. Water flowing from top to bottom (extracted from finn.no, map data delivered by Norkart)

Flow metrics (1987-2016)

MAF (m^3/s):	0.87
M_{AMD} (day):	6
CV_{AMD} (day):	2.22
τ:	26 February
$τ_r$:	0.81
k:	0.85
M_{AN} (day):	8
CV_{AN} (day):	2.20

Description and reasons for intermittence

The main reason for intermittence is snow accumulation during winter, and the zero-flow events happen in the period December to April. The catchment is small and there are relatively thin till soils covering the underlying bedrock. More than 50% of the catchment has no soils. This catchment therefore easily dries out.

Spatial pattern: Unknown

Seasonality: Almost all intermittent events are from the winter/spring season.

Driver(s): ☐ Summer dry period ☒ Freezing/snow ☐Water management
☐Interaction with groundwater ☐ Other:

Observations of intermittence

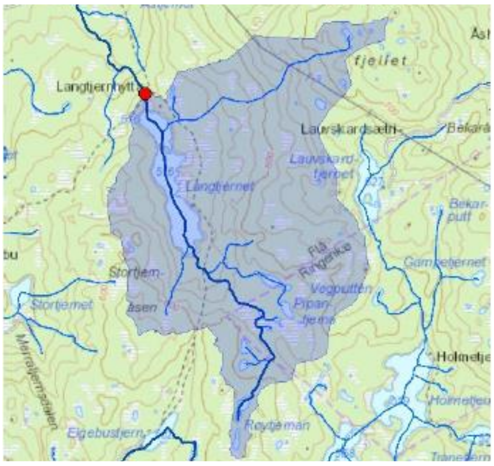
Gauging station(s): The observations are from the streamflow gauging station Håkådalselv (number 109.35.0 in the NVE database). This example of stations with intermittent streamflow was extracted from the Norwegian hydrological database hosted by NVE. The Håkådalselv gauging station is one of the available gauging stations with no influence from reservoirs, with the best quality of low flow measurements, and with the largest number of zero-flow events. The observation is based on zero flow in natural profile, and the lowest direct measurement of streamflow is 0.2 m^3s^{-1}, and the zero-point of the rating curve is not well established. A major challenge is data quality for winter low flows: values were gap-filled or corrected due to formation of ice in the river before displaying hydrographs and curves in the first page.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): No information on aquatic states is available for this small stream.

Author(s): Kolbjørn Engeland (koe@nve.no)

17. Langtjernbekk (NORWAY)

Vest Viken



Map of the Langtjernbekk catchment. Made in nevina.nve.no

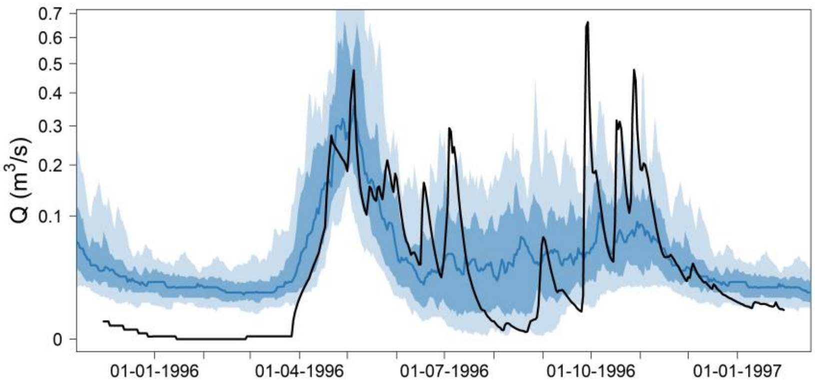
Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Langtjernbekk
Coordinates (°): 60.3727, 9.7275 (WGS84)
Catchment area (km²): 4.67
Characteristic channel width: ☐ <1 m ☐1-5 m ☐ >5 m ☒Unknown
River length (km): 3.81
Elevation range (m a.s.l.): 518 to 757

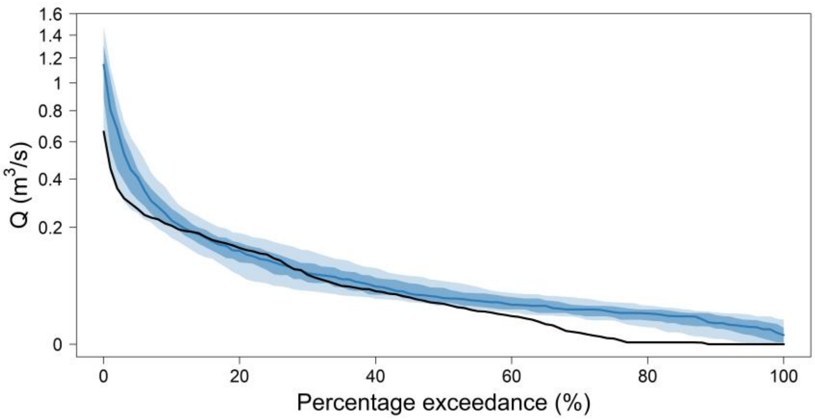
Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒ Other: Gneiss covered with thin till soils

Climate:
Mean annual precipitation (mm/year): 790
Mean annual temperature (°C): 1.2
Köppen class: Subartic climate (Dfc)

Land use (forest and natural, agricultural, wetlands, artificial): Forest (86%), lakes (6.8 %), bogs (6.7%)

Artificial influence: None





Hydrographs and flow duration curves of the Langtjernbekk at Langtjernbekk (1973-2018) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Aerial photo of the small stream just downstream the gauging station. Water flowing from bottom to top (extracted from finn.no, map data delivered by Norkart)

Flow metrics (1973-2018)

MAF (m^3/s): 0.10

M_{AMD} (day): 13
CV_{AMD} (day): 1.88
τ: 18 July
τ_r: 0.79
k: 0.84
M_{AN} (day): 14
CV_{AN} (day): 1.82

Description and reasons for intermittence

The main reason for intermittence is low precipitation and high evapotranspiration. The catchment is small and there are relatively thin till soils covering the underlying bedrock that is mainly Gneiss. This catchment therefore easily dries out. The gauging station is located downstream a small lake.

Spatial pattern: Unknown.

Seasonality: Almost all intermittent events are from the summer season. Only one event during winter 1995 that was a dry and cold winter.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☐Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): The observations are from the streamflow gauging station Langtjernbekk (number 12.188.0 in the NVE database). This example of stations with intermittent streamflow was extracted from the Norwegian hydrological database hosted by NVE. The Langtjernbekk gauging station is one of the available gauging stations with no influence from reservoirs, with the best quality of low flow measurements, and with the largest number of zero-flow events. The observation is based on zero flow in a sharp V-notch weir, and the zero-point of the gauging station is well established.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): No information on aquatic states is available for this small stream.

Author(s): Kolbjørn Engeland (koe@nve.no)

18. Tjellingtjernbekk (NORWAY)

Agder

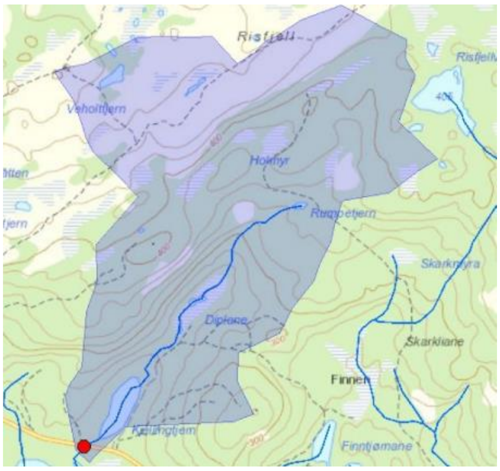
Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Tjellingtjernbekk
Coordinates (°): 58.9321, 8.8594 (WGS84)
Catchment area (km²): 1.95
Characteristic channel width: ☐ <1 m ☐1-5 m ☐ >5 m ☒Unknown
River length (km): 1.67
Elevation range (m a.s.l.): 223 to 499

Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite) ☐Unknown ☒ Other: Gneiss covered with shallow till soils, exposed bedrock in highest altitudes

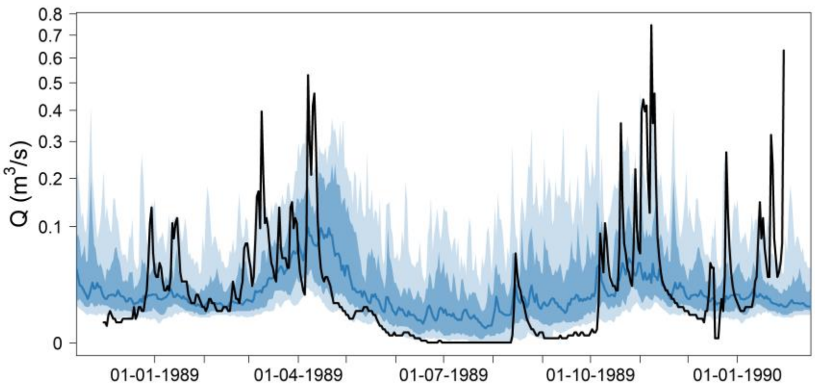
Climate:
Mean annual precipitation (mm/year): 1558
Mean annual temperature (°C): 4.2
Köppen class: Subartctic (Dfc)

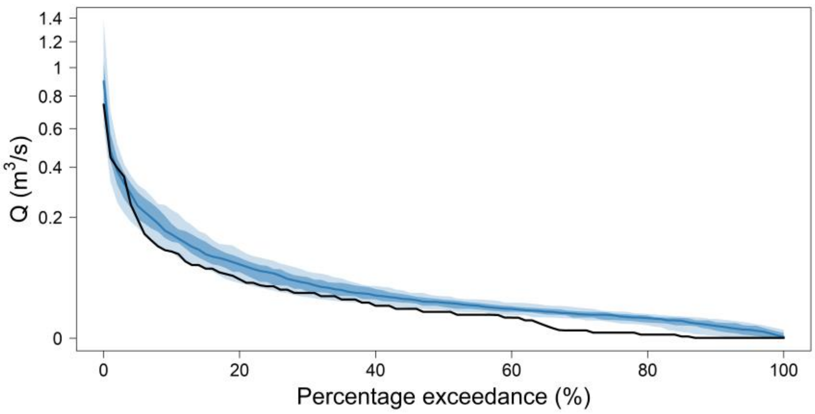
Land use (forest and natural, agricultural, wetlands, artificial): Forest (67%), open areas above timber line (9.1 %), bogs (5.7%), lakes (1.7 %)

Artificial influence: None



Map of the Tjellingtjernbekk catchment. Made in nevina.nve.no





Hydrographs and flow duration curves of the Tjellingtjernbekk at Tjellingtjernbekk (1981-2018) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Aerial photo of the small stream just upstream the gauging station. Water flowing from top to bottom (extracted from finn.no, map data delivered by Norkart)

Flow metrics (1981-2018)

MAF (m^3/s): 0.06

M_{AMD} (day): 20
CV_{AMD} (day): 0.98
$\tau 0$: 20 June
$\tau 0_r$: 0.85
k: 0.72
M_{AN} (day): 28
CV_{AN} (day): 0.95

Description and reasons for intermittence

The main reason for intermittence is low precipitation and high evapotranspiration. The catchment is small and there are relatively thin till soils covering the underlying bedrock that is mainly Gneiss. This catchment therefore easily dries out. The gauging station is located just downstream a small lake.

Spatial pattern: Unknown.

Seasonality: All intermittent events are from the summer season.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☐Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): The observations are from the streamflow gauging station Tjellingtjernbekk (number 18.11.0 in the NVE database). This example of stations with intermittent streamflow was extracted from the Norwegian hydrological database hosted by NVE. The Tjellingtjernbekk gauging station is one of the available gauging stations with no influence from reservoirs, with the best quality of low flow measurements, and with the largest number of zero-flow events. The observation is based on zero flow in a sharp V-notch weir, and the zero-point of the gauging station is well established.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): No information on aquatic states is available for this small stream.

Author(s): Kolbjørn Engeland (koe@nve.no)

19. Tveitdalen (NORWAY)

Agder

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Tveitdalen
Coordinates (°):58.3854, 8.2424 (WGS84)
Catchment area (km^2): 0.44
Characteristic channel width: ☐ <1 m ☐1-5 m ☐ >5 m ☒Unknown
River length (km): 0.61
Elevation range (m a.s.l.): 191 to 239

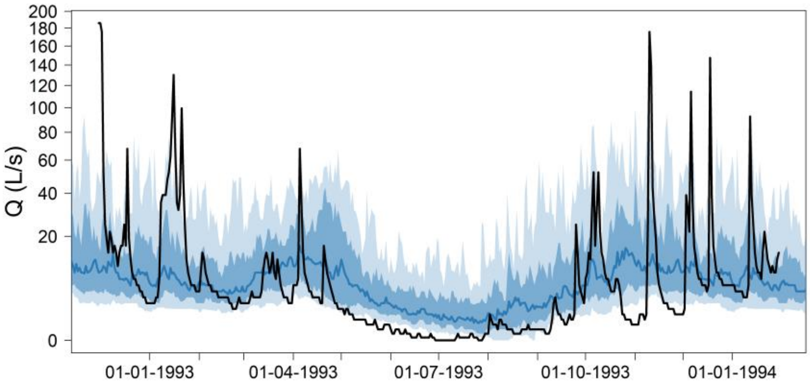
Map of the Tveitdalen catchment. Made in nevina.nve.no

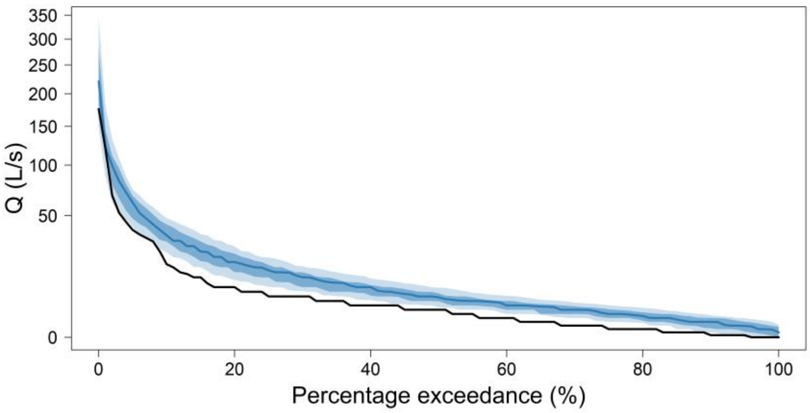
Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒ Other: Granite covered with shallow till soils

Climate:
Mean annual precipitation (mm/year): 1405
Mean annual temperature (°C): 5.9
Köppen class: Warm-summer humid continental/subarctic climate **(**Dfb/Dfc)

Land use (forest and natural, agricultural, wetlands, artificial): Forest (100%)

Artificial influence: None





Hydrographs and flow duration curves of the Tveitdalen at Tveitdalen (1972-2018) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Aerial photo of the small stream just upstream the gauging station. Water flowing from left to right (extracted from finn.no, map data delivered by Norkart)

Flow metrics (1972-2018)

MAF (m^3/s):	0.01
M_{AMD} (day):	25
CV_{AMD} (day):	0.71
$\tau 0$:	1 June
$\tau 0_r$:	0.75
k:	0.77
M_{AN} (day):	52
CV_{AN} (day):	0.63

Description and reasons for intermittence

The main reason for intermittence is low precipitation and high evapotranspiration. The catchment is small and there are relatively thin till soils covering the underlying bedrock that is mainly Gneiss. This catchment therefore easily dries out. The gauging station is located just downstream a small lake.

Spatial pattern: Unknown.

Seasonality: Most intermittent events are from the summer season.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☐Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): The observations are from the streamflow gauging station Tveitdalen (number 20.11.0 in the NVE database). This example of stations with intermittent streamflow was extracted from the Norwegian hydrological database hosted by NVE. The Tveitdalen gauging station is one of the available gauging stations with no influence from reservoirs, with the best quality of low flow measurements, and with the largest number of zero-flow events. The observation is based on zero flow in a V-notch weir, and the zero-point of the gauging station is well established.

Flow/aquatic state observations (e.g. “flow”, “disconnected pools”, “dry bed”): No information on aquatic states is available for this small stream.

Author(s): Kolbjørn Engeland (koe@nve.no)

20. Czarna (POLAND)

Kanał Żerański

Characteristics from the catchment at: ☐ the outlet
☐ the gauging station: Czarna at Struga
Coordinates (°):52.3652, 21.1389 (WGS84)
Catchment area (km²): 198.2
Characteristic channel width: ☐ <1 m ☒1-5 m ☐ >5 m ☐Unknown
River length (km): 9.4
Elevation range (m a.s.l.): 79 to 205

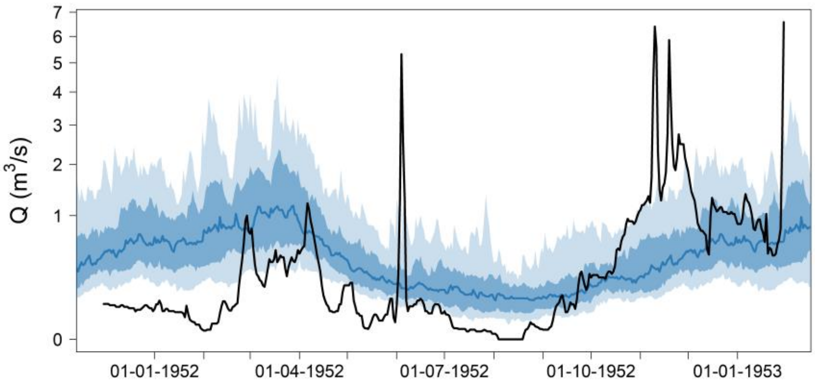
Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☐Other: Sedimentary

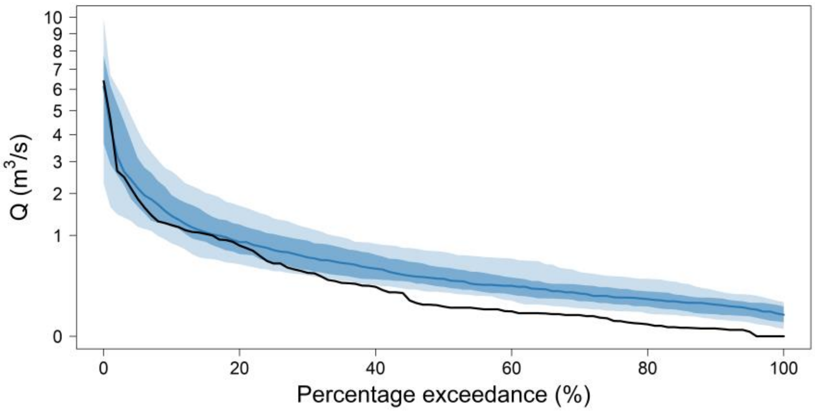
Climate:
Mean annual precipitation (mm/year): 534
Mean annual temperature (°C): 8.2
Köppen class: Warm-summer humid continental climate (Dfb)

Land use (forest and natural, agricultural, wetlands, artificial): Artificial surfaces (18.5%), Agricultural areas (49.8%), forests (30.5%), wetlands (0.9%), water bodies (0.3%)

Artificial influence: Unknown

The River Czarna.
http://marki.wikia.com/wiki/Czarna_Struga_(rzeka)





Hydrographs and flow duration curves of the Czarna at Struga (1950-2017) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

The Czarna River in October 2010. Photo taken from the bridge on street Spacerowa.
http://marki.wikia.com/wiki/Czarna_Struga_(rzeka)

Flow metrics (1950-2017)

MAF (m^3/s):	0.70
M_{AMD} (day):	0.4
CV_{AMD} (day):	5.76
$\tau 0$:	7 August
$\tau 0_r$:	0.95
k:	0.84
M_{AN} (day):	0.4
CV_{AN} (day):	5.42

Description and reasons for intermittence

Czarna, also Czarna Struga or Struga, is a river in the Mazowieckie Voivodeship, flowing through the Legionowo county and the Wołomin county and having its outlet in the Żerań Canal. In the lower reaches, the river flows through the nature reserve of Łęgi Czarna Struga in the commune of Nieporęt and the Puszcza Słupecka nature reserve.

The regime type is nival. Floods are observed in spring due to snowmelt and in summer (June-July) due to convective precipitation. Low flows usually occur from June to November in this region and result from precipitation deficit.

Spatial pattern: Unknown.

Seasonality: Summer dry period

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☐Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): Daily river discharge data (years 1950-2017) were obtained from the Institute of Meteorology and Water Management National Research Institute, Poland (acronym: IMGW-PIB). Zero flows were observed at the Struga gauging station. Missing data for the following periods: 01/11/1989-31/10/1992, 01/11/2005-31/10/2006, and 04/08/2015-21/10/2015.

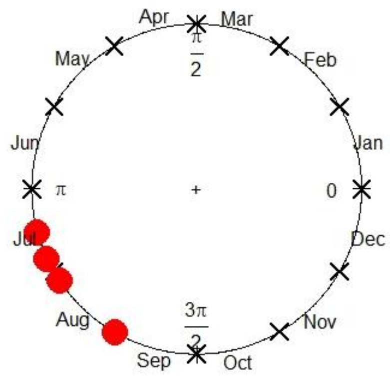
Flow/aquatic state observations (e.g. “flow”, “disconnected pools”, “dry bed”): Zero flows were observed in 1952 (17 days), 1976 (8 days) and 1983 (2 days).

Climate

The climate of the Czarna catchment is relatively mild with well-pronounced seasonality (cold winters with snow and warm summers). The winter months are generally the driest while the largest precipitation amounts in June and July. Estimated values of both mean annual rainfall (MAR) and mean annual air temperature (MAT) are based on data from the Warszawa meteorological station from the period 01/01/1966-31/12/2010.

Timing of intermittence

The periods of intermittence occurred with seasonal pattern in years 1952, 1976, 1983. All first days of intermittence (four events) were depicted in red in the circular diagram below. The low dispersion of the days of drying is reflected in a high value of $\tau0_r > 0.9$ (cf. box “Flow metrics”, first page). Lengths of the periods vary from 2 to 17 days.



Author(s): Marzena Osuch (marz@igf.edu.pl), Agnieszka Rutkowska (rmrutkow@cyf-kr.edu.pl)

21. Goryczkowy Potok (POLAND)

Tributary of the Bystra Potok

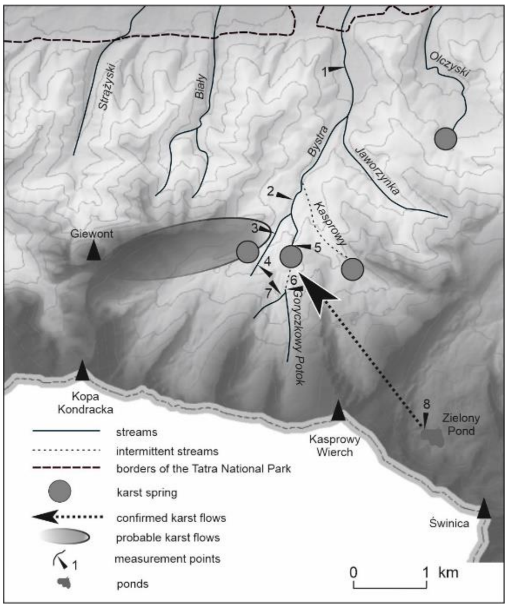
Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Goryczkowy Potok Tatra National Park
Coordinates (°): 49.2454, 19.9683 (WGS84)
Catchment area (km²): 1.88
Characteristic channel width: ☒ <1 m ☐ 1-5 m ☐ >5 m ☐Unknown
River length (km): 2.95 km
Elevation range (m a.s.l.): 1314 to 1987

Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒Other: Crystalline

Climate:
Mean annual precipitation (mm/year): ≈ 1797
Mean annual temperature (°C): ≈ -0.5
Köppen class: Warm-summer humid continental climate (Dfb)

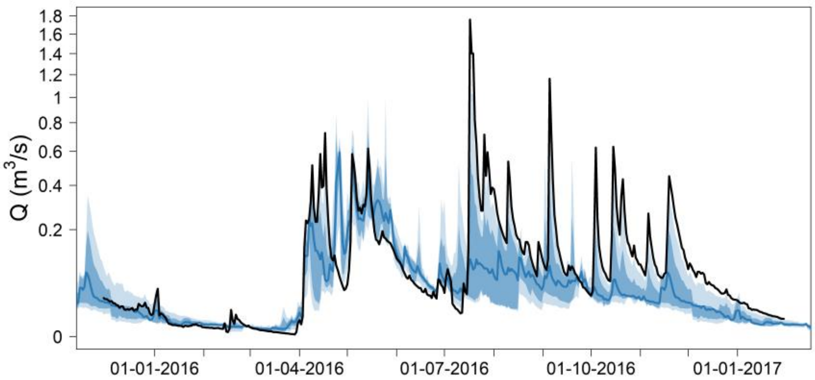
Land use (forest and natural, agricultural, wetlands, artificial): Forest and semi natural areas (100%) (source: Corine Land Cover 2018) including mountains pine, alpine grassland, poor rock vegetation (alpine lichens and alpine flowers)

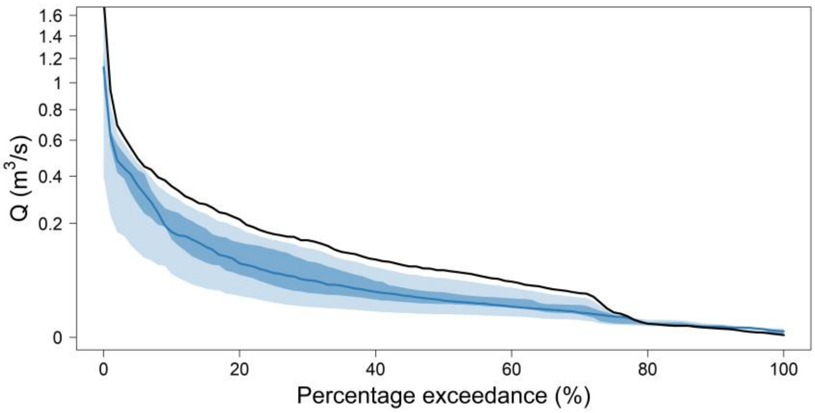
Artificial influence: No influence



Map of the Goryczkowy Potok and some other Tatra streams (Sajdak *et al.*, 2018)

The Goryczkowy Potok Potok in summer and winter (source: Monika Sajdak, Mirosław Żelazny)





Hydrographs and flow duration curves of the Goryczkowy Potok at Goryczkowy Potok (2013-2017) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Flow metrics (2013-2017)

MAF(m^3/s):	0.09
M_{AMD}(day):	11
CV_{AMD}(day):	0.80
τ0:	27 February
$τ0_r$:	0.98
k:	0.86
M_{AN} (day):	12
CV_{AN} (day):	0.84

Description and reasons for intermittence

The Goryczkowy Potok is located in the Tatra Mountains which is a part of the Carpathian Mountains. The streambed is composed of sediments and granite rock. Steep rock shelves reaching a height of 10 m, cause rapid water falling. The water loss is due to hydro-geological conditions because the Goryczkowa Valley is dichotomic from geological point of view with crystalline texture in the upper part and karst area in the middle part. Snowfall has a significant share in the structure of precipitation. Usually, two periods of low flows or water loss are observed, namely in late summer because of low rainfall amounts and in late winter because of accumulated snow packs that do not melt due to very cold temperatures. The Goryczkowy Potok is a right tributary of the Bystra River.

Spatial pattern: Intermittence in the middle course.

Seasonality: A strong seasonal pattern. Intermittence is always observed in late winter-early spring (February-March).

Driver(s): ☐ Summer dry period ☒ Freezing/snow ☐Water management
☐Interaction with groundwater ☒ Other: hydro-geological conditions (crystalline texture in the upper part and karst area in the middle part)

Observations of intermittence

Gauging station(s): The owners of the river discharge data (years 2014-2017) from the gauging station Goryczkowy Potok are: Institute of Geography and Spatial Management, Jagiellonian University in Kraków and Polskie Koleje Linowe S.A. Zakopane.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): Intermittence was observed every year during the period 2014-2017 in the time series of daily discharges at the Goryczkowy Potok gauging station.

Climate

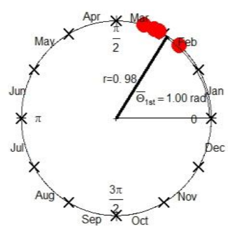
The climatic, vegetation and morphogenetic conditions of the Tatra Mountains are very diverse due to a wide range of topographical gradient and altitude and due to a variety of processes in geological epochs, for example during the Pleistocene glaciations when the valleys were transformed from V-shaped to U-shaped and moraine were created. The topography was shaped during this period which caused various forms resulting from glacial processes (moraines, cirques, tarns, paternoster lakes, rocks, caves). Climate is influenced by oceanic and continental air masses for which the mountains are the natural barrier to the north-south movement. Climate zones change with altitude from moderately cool to cold. The rainfalls/snowfalls increase with increasing altitude. The complexity and diversity of climatic, physiographic and geological conditions in the Tatra Mountains is reflected in a large variability of water level, river discharge, precipitation, infiltration and others. The crystalline part of the Goryczkowy catchment is characterized by very low mineralization of waters and a low nitrate concentration. Spring is characterized by a greater diversification of the chemical composition of waters than other seasons. Estimated values of both mean annual rainfall (MAR) and mean annual air temperature (MAT) are based on data from the Kasprowy Wierch station located 2 km from the Goryczkowy Potok gauging station.

Niedźwiedź T. (1992). Climate of the Tatra Mountains. Mountain Research and Development, 12(2), 131—146, DOI: 10.2307/3673787.

Sajdak *et al*. (2018). Hydrological and chemical water regime in the catchments of Bystra and Sucha Woda, in the Tatra

Timing of intermittence

The periods of intermittence occurred every year, with a clear seasonal pattern. The days of onsets were depicted in red in the circular diagram below. The high concentration is reflected in a very high mean resultant length of the onsets equal to 0.98.



Author(s): Mirosław Żelazny (mirosław.zelazny@uj.edu.pl), Marzena Osuch (marz@igf.edu.pl)

22. Noteć (POLAND)

Warta River basin

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Noteć at Łysek
Coordinates (°): 52.4069, 18.5042 (WGS84)
Catchment area (km²): 306
Characteristic channel width: ☐ <1 m ☐1-5 m ☐ >5 m ☒Unknown
River length (km): 51.9
Elevation range (m a.s.l.): 84 to 188

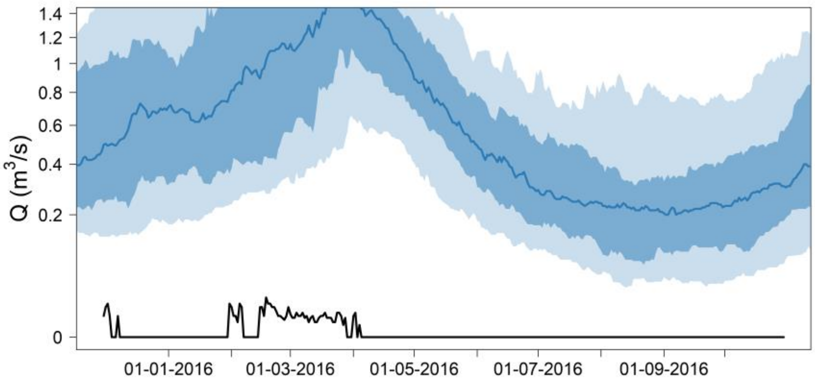
The gauging site at Łysek (Oct. 2018).
https://ziemianarozdrozu.pl/artykul/3731/smutny-widok-znikajacych-jezior-raport-z-dnia-28-pazdziernika-2017-roku

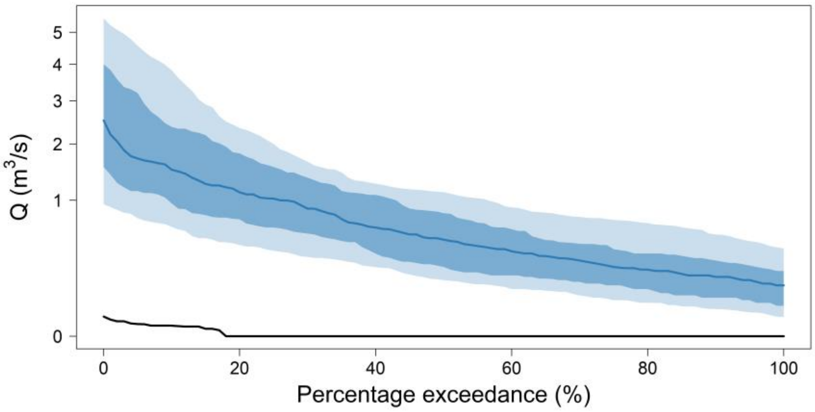
Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite) ☐Unknown ☒Other: Sedimentary

Climate:
Mean annual precipitation (mm/year): 534
Mean annual temperature (°C): 8.45
Köppen class: Warm-summer humid continental climate (Dfb)

Land use (forest and natural, agricultural, wetlands, artificial): Forest and semi natural areas (77.0%), agricultural areas (15.5%), wetlands (2.6%), water bodies (2.4%), artificial surfaces (2.5%)

Artificial influence: Mining operations may have significant impacts on groundwater levels





Hydrographs and flow duration curves of the Noteć at Łysek (1960-2016) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

The dry riverbed at the Łysek gauging station (2017).
https://www.facebook.com/odkrywka.info/photos/a.637800406333321/1205710392875650/?type=3&theater

Flow metrics (1960-2016)

MAF (m^3/s):	0.82
M_{AMD} (day):	5
CV_{AMD} (day):	5.86
τ0:	26 August
$τ0_r$:	0.35
k:	0.94
M_{AN} (day):	7
CV_{AN} (day):	5.45

Description and reasons for intermittence

The Noteć River flows through central Poland. Its catchment is a part of the Odra River basin, the second longest river of Poland. The regime type is nival. Three main droughts were observed during the last 60 years: 1951-1959, 1982-1994, 2001-2008. Lengths of droughts correspond with atmospheric droughts and with decreasing trend in precipitation. Apart from the impact of atmospheric drought on river flows, also the open pit lignite mines (Konin, Tomisławice) caused perturbations in groundwater supply and resulted in river intermittence due to a large cone of depression around the mines. Also, several lakes from neighbourhood dried up.

Bartczak A., Glazik R., Tyszkowski S., 2014. Identyfikacja i ocena intensywności okresów suchych we wschodniej części Kujaw (Identification and evaluation of the intensity of dry periods in eastern part of Kujawy). Nauka Przyr. Technol. 8, 4, #46.

Wrzesiński D., Perz A. 2016. Cechy reżimu odpływu rzek w zlewni Warty Badania fizjograficzne R. VII – SERIA A – Geografia Fizyczna (A67), 289–304. doi 10.14746/bfg.2016.7.21

Spatial pattern: Intermittence in the upper course.

Seasonality: No seasonality was observed in intermittence.

Driver(s): ☐ Summer dry period ☐Freezing/snow ☒Water management
☒Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): There is one gauging station located at Łysek. The river intermittence was observed in 1992 (4 days), 2015 (141 days) and 2016 (252 days). Daily river discharge data (years 1960-2016) were obtained from the Institute of Meteorology and Water Management National Research Institute, Poland (acronym: IMGW-PIB).

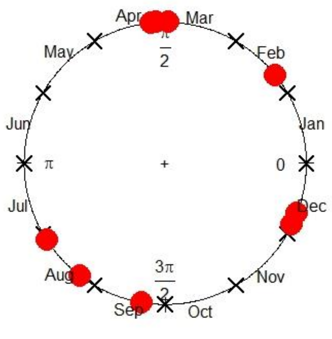
Flow/aquatic state observations (e.g. “flow”, “disconnected pools”, “dry bed”): Zero flows have been observed at the Łysek gauging station. The dry bed has length of approximately 30 km.

Climate

The climate of the Noteć catchment is relatively mild. However, the area is one of the driest areas in Poland and it is exposed to a significant deficiency of water resources. Low river flows occur usually from June to November in this region. Estimated values of both mean annual rainfall (MAR) and mean annual air temperature (MAT) are based on data from the Koło meteorological station from the period 01/01/1966-31/12/2010.

Timing of intermittence

The periods of intermittence occurred with no clear seasonal pattern in years 1992, 2015 and 2016. All first days of intermittence (nine events) were depicted in red in the circular diagram below. The dispersion of the days of drying is reflected in the low value of the mean resultant length τ_r equal to 0.33 (cf. box “Flow metrics”, first page). This low value confirms that the intermittence pattern is unseasonal. Also, lengths of the periods vary from 1 day to 209 days.



Author(s): Agnieszka Rutkowska (rmrutkow@cyf-kr.edu.pl), Marzena Osuch (marz@igf.edu.pl)

23. Zagożdżonka (POLAND)

South part of Mazovia / within the Vistula River basin

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Zagożdżonka at Wygoda
Coordinates (°): 51.41978, 21.43038 (WGS84)
Catchment area (km²): 9.3
Characteristic channel width: ☒ <1 m ☐1-5 m ☐ >5 m ☐Unknown
River length (km): 4.45
Elevation range (m a.s.l.): 163.5 to 182

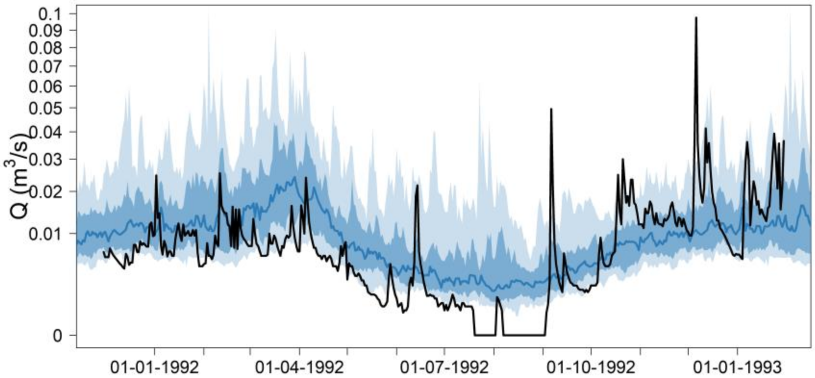
Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒Other: Sedimentary (Mazovian interglacial)

Climate:
Mean annual precipitation (mm/year): 610
Mean annual temperature (°C): 8.4
Köppen class: Temperate/Humid continental climate (Dfb)

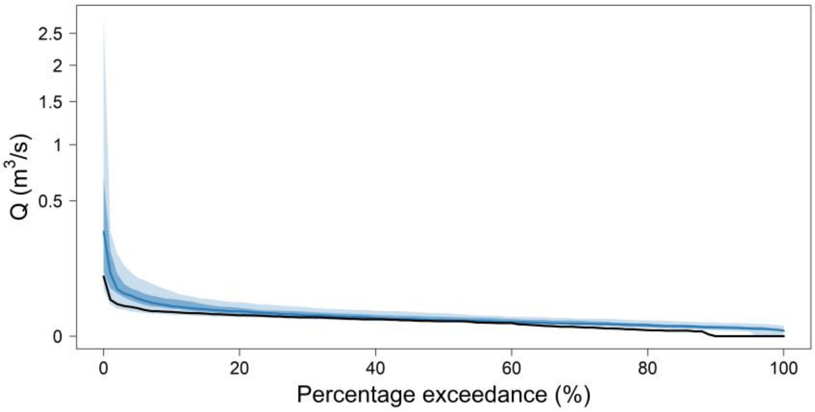
Land use (forest and natural, agricultural, wetlands, artificial): Forest and natural (44%), agricultural (41%), pasture & wetlands (14%), artificial (1%)

Artificial influence: Unknown

Dry bed - view of the gauging station at Wygoda - looking downstream. Photo: Kazimierz Banasik; date: 31/08/1992



View of the gauging station at Wygoda - looking upstream. Photo: Kazimierz Banasik; date: 10/05/1994

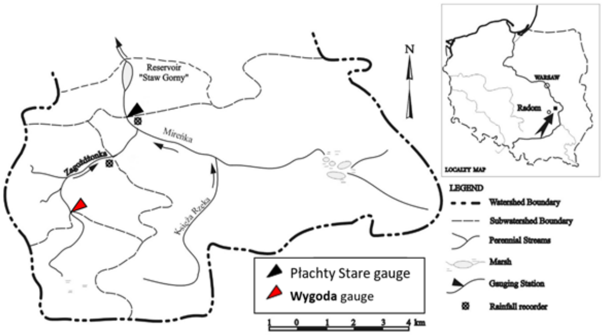


Hydrographs and flow duration curves of the Zagożdżonka at Wygoda (1980-2015) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Flow metrics (1980-2015)

MAF (m^3/s):	0.02
M_{AMD} (day):	6
CV_{AMD} (day):	1.41
$\tau 0$:	14 July
$\tau 0_r$:	0.85
k:	0.83
M_{AN} (day):	13
CV_{AN} (day):	1.45

Description and reasons for intermittence



The Zagożdżonka River is left tributary of the Vistula River with its outlet (N: 51°39'28"; E: 21°29'13") near Kozienice town. In the upstream part of the river, there have been three gauging stations - at Płachty Stare (with catchment area *A*= 82.4 km²), Czarna (*A*= 23.4 km²) and Wygoda (*A*= 9.3 km²), at which discharges have been monitored by the Department of Hydraulic Structures of Warsaw University of Life Sciences – SGGW. Only in the most upstream gauging station intermittence of flow was observed. So, discharges at the gauge Wygoda only, are analysed.

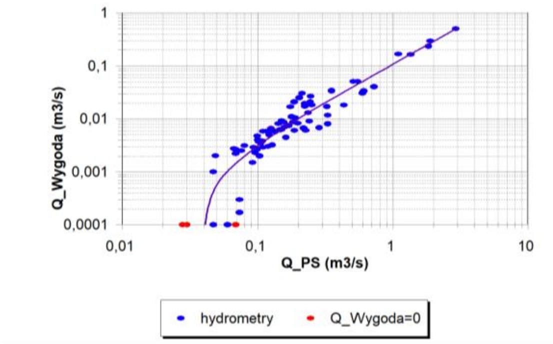
Spatial pattern: Zero flows are occasionally observed only in the upstream part of the river (at Wygoda gauging station).

Seasonality: No flow was observed on average in one per seven years. In the year with no flow there were on average over 20 days with dry bed. It happens usually in July and/or August.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☒Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s):



As the river gauge station Wygoda at Zagożdżonka River has been monitored in the period 1980-2015 only periodically, the analysis is based on the discharge relationship with the flow at Płachty Stare (Banasik and Hejduk L., 2012; Banasik *et al*., 2013; Kaznowska and Banasik, 2011). The graph on the left shows the relation of corresponding discharges of the Zagożdżonka River at the Płachty Stare gauge (Q_PS, as denor side) and the Wygoda gauge (investigated site). Blue dots represent semi-simultaneous hydrometric measurements of discharge at the gauges, and the red dots dry bed at Wygoda.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): During the 1980-2015 there were five years with dry bed periods, *i.e*. 1989, 1992, 1994, 2013 and 2015 with 16, 41, 18, 31 and 22 days of zero flows, respectively.

Banasik K., Hejduk L. (2012). Long-term changes in runoff from a small agricultural catchment. Soil and Water Research, 7, 64-72.

Banasik *et al*. (2013). Long-term variability of runoff from a small catchment in the region of the Kozienice forest. Sylwan, 157, 578-586.

Kaznowska E., Banasik K. (2011). Streamflow droughts and probability of their occurrence in a small agricultural catchment. Annals of Warsaw University of Life Sciences-SGGW. Land Reclamation, 43, 57-69.

Views of Zagożdżonka River at two sites

Views of the gauging stations: Płachty Stare - denor site (on the left) and Wygoda - investigated site (on the right), during high flow period (photos taken by K. Banasik in December 1994).

Author(s): Kazimierz Banasik (kazimierz_banasik@sggw.pl)

24. Algibre (PORTUGAL)

Quarteira River Basin (Algarve River Basin District)

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Purgatório (30J/02HA)
Coordinates (°): -8.209282, 37.176437 (WGS84)
Catchment area (km²): 295
Characteristic channel width: ☐ <1 m ☐1-5 m ☒ >5 m ☐Unknown
River length (km): 29
Elevation range (m a.s.l.): 53 to 234

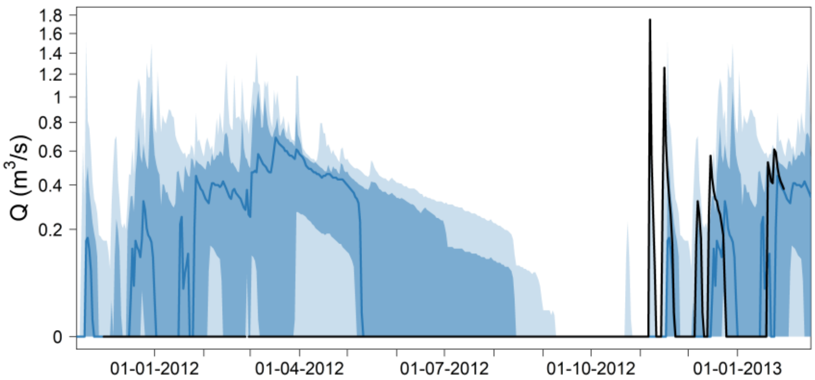
Geology: ☒ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☐Other: sedimentary

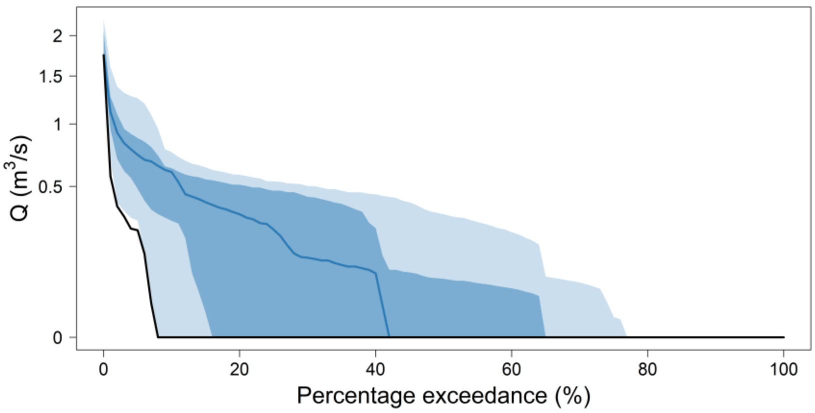
Climate:
Mean annual precipitation (mm/year): 670
Mean annual temperature (°C): 16.6
Köppen class: Hot-summer Mediterranean climate (Csa)

Land use (forest and natural, agricultural, wetlands, artificial): Forest (54%), agriculture (45.5%), industry (0.2%), urban (0.3%) (Source: Corine Land Cover 2006)

Artificial influence: Groundwater and superficial water abstraction for irrigation

A pool in the middle part of the river (Coord: -8.023511, 38.853160). Date: 11/06/2014





Hydrographs and flow duration curves of the Quarteira at Purgatório (2005-2014) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Dry riverbed near Purgatório gauging station (Coord. -8.211268, 38.706242). Date: 16/02/2012

Flow metrics (2005-2014)

MAF (m³/s): 0.19

M_{AMD} (day): 178
CV_{AMD} (day): 0.61
$\tau 0$: 4 December
$\tau 0_r$: 0.55
k: 0.91
M_{AN} (day): 216
CV_{AN} (day): 0.48

Description and reasons for intermittence

The Algibre River presents a strong relationship with groundwater. Headwaters are located on Palaeozoic rocks with low permeability and the stream only dries for a few days during the dry season or for a higher number of days during dry years. In its downstream stretch, Algibre River crosses a karst aquifer system (Querença - Silves), which geological formations have a high infiltration capacity. In some river sections, the river recharges the aquifer, while in others the river is fed by the discharge of the aquifer, being the connection established superficially. Due to water infiltration, the riverbed remains dry during the dry season on most part of its course. There are only a few pools upstream fed by permanent springs, whose waters infiltrate again a few meters downstream.

Spatial pattern: Intermittent in the whole course, mainly in the middle stretch.

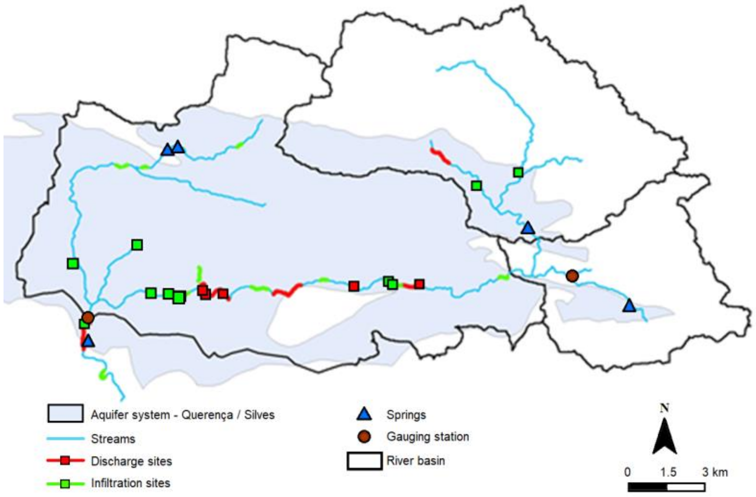
Seasonality: Flow ceases every year mainly in summer end early autumn, but some isolated pools remain during this period. The pools upstream are fed by permanent springs.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☒Water management
☒Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): In this catchment there are two gauging stations: Querença (30J/01HA) and Purgatório (30H/02HA). These gauging stations have data for a period of 8 to 10 years. Querença (30J/01HA) is located upstream the aquifer and the flow in this station is higher than in Purgatório, located downstream.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): The stream is characterized by a Mediterranean-type climate, where most of the biological, chemical and physical processes are shaped by sequential events of annual flooding and drying. In the wet season, due to the torrential rainfall regime, the flow is high and there are frequent floods. In the dry season, due to interaction with groundwater, much of the stream is dry and there are only disconnected pools.



Relationship between groundwater and surface water

Wet periods start in late October and last until March, with high discharge peaks, while from late June until September, the dry season proceeds, leaving temporarily disconnected pools or completely dry channels. Land use is mainly arable land accompanied by shrub and herbaceous vegetation, and mixed forests. Woody vegetation in the catchment consists of olive trees and other cultivation trees, such as almond, cork oak and citrus. The lower reaches are particularly associated with the giant reed (*Arundo donax*) that in some places forms impenetrable thickets, which are the dominant type of riparian vegetation. Such land use characteristics, along with scant urban development, makes the catchment relatively undisturbed.

Author(s): Edite Reis (edite.reis@apambiente.pt)

25. Almansor / Ribeira de Santo Estevão / Ribeira de Canha (PORTUGAL)

Tagus River Basin District

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Ponte Canha (21F/01H)
Coordinates (°): 38.765, -8.617 (WGS84)
Catchment area (km²): 493.8
Characteristic channel width: ☐ <1 m ☐1-5 m ☒>5 m ☐Unknown
River length (km): 100
Elevation range (m a.s.l.): 0 to 400

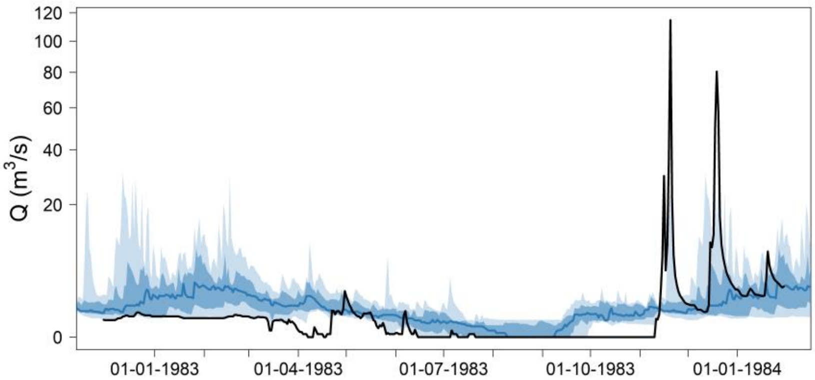
Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒Other: Sedimentary

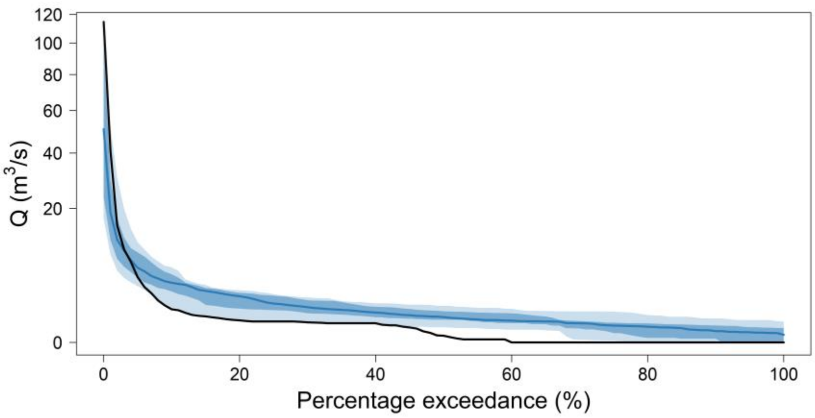
Climate:
Mean annual precipitation (mm/year): 100-150
Mean annual temperature (°C): ≈15.5
Köppen class: Hot-summer Mediterranean climate (Csa)

Canha River bed downstream Ponte Canha (21F/01H) gauging station. Date: 24/07/2002

Land use (forest and natural, agricultural, wetlands, artificial): Forest (≈52%), agriculture (≈19%), agroforestry systems (≈19%), pastures (≈7 %)

Artificial influence: The natural flow regime is affected by the Minutos dam used for irrigation and located at the river headwaters, although an eflow regime is already implemented, the runoff of irrigated land, mainly during summer, the existence of water intakes directly from the river for irrigation of small nearby cultivated areas, and the presence of small dams in the catchment also for irrigation and livestock drinking water





Hydrographs and flow duration curves of the Rio Almansor or Ribeira de Santo Estevão or Ribeira de Canha at Ponte Canha (21F/01H) gauging station (1979-1990) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

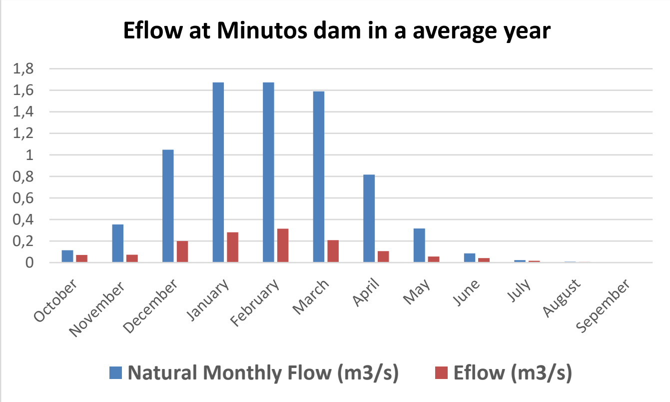
Canha River at Ponte Canha (21F/01H) gauging station. Date: 07/04/2017

Flow metrics (1979-1990)

MAF (m^3/s):	2.11
M_{AMD} (day):	36
CV_{AMD} (day):	1.28
τ0:	3 June
$τ0_r$:	0.60
k:	0.85
M_{AN} (day):	41
CV_{AN} (day):	1.32

Description and reasons for intermittence

The precipitation at Ponte Canha gauging station (21F/01H) presents an annual mean of about 600-700 mm, and is irregularly distributed throughout the year and between years. The number of days with precipitation varies between 50 and 75 and most rainfall occurs seasonally, from late autumn to early spring. As consequence, there is high variability of the flow regime throughout the year, with long periods without flow, and also of the runoff between dry and wet years. The natural flow regime is affected by the Minutes dam used for irrigation and located at the river headwaters, although an eflow regime is already implemented, the runoff of irrigated land, mainly during summer, water abstraction directly from the river for irrigation of small nearby cultivated areas and the presence of small dams in the catchment also for irrigation and livestock drinking water.



Additionally, a flood flow with a return period of two years is discharged each year in February, the month with the highest average monthly flow. It was also defined an eflow regime for dry years

Spatial pattern: Canha River is a naturally Mediterranean intermittent river in its whole length.

Seasonality: No flow during summer, between June and October, for one to four months, depending on the characteristics of the hydrological year. In dry years the period with no flow can be longer than six months. During the dry season, some pools remain in the river bed.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☒Water management
☐Interaction with groundwater ☐ Other: water uses

Observations of intermittence

Gauging station(s): The only gauging station on the Canha River is Ponte Canha (21F/01H). This gauging station has data from 1979 until 2011. The flow regime is only characterized by the flow data. There is no systematic record of the aquatic state observations.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): Canha River presents flow during late autumn, winter and spring and disconnected pools during summer. At the end of summer until the beginning of autumn the river can become dry at least at certain reaches.

Ecological Characterization

The upper reach of Canha River belongs to the type Southern Medium-Large Rivers with a drainage basin larger than 100 km^2, and the downstream reach, where the Ponte Canha gauging station (21F/01H) is located belongs to the type Sedimentary Deposits of Tagus and Sado. The upper part of the catchment is siliceous and the downstream part is characterized by sedimentary and alluvial deposits. On the downstream reach, where the Canha gauging station (21F/01H) is located, the substrate of the river bed is dominated by sand and, to a lesser extent, gravel. The downstream river reach presents, in winter, continuous runs of low depth, since the type of substrate does not favour the sequence of riffles / pools, consequently, the frequency of riffles is small during winter and spring. In summer and early autumn there is no superficial flow, and only some pools remain on the river bed during this period. In what refers to macroinvertebrates the most representative families of Ephemeroptera are Baetidae (*Baetis* sp.), Caenidae (*Caenis* sp.), Ephmerellidae (*Habrophlebia* sp.), Leptophlebidae, while the Plecoptera are absent; and Diptera by Simuliidae and Chironomidade. It is highlighted the high diversity of Diptera observed in the summer pools. Diatom community presents a high diversity, being the more abundant specie: *Cocconeis lineata*, *Diadesmis confervacea*, *Melosira varians*, *Planothidium frequentissimum*, *Planothidium lanceolatum*, *Sellaphora seminulum.* The riparian vegetation is in good conditions and presents all the stratus. The dominant trees are ash trees (*Fraxinus angustifolia* subsp. *Angustifolia*), willows (*Salix salviifolia, Salix atrocinera),* and poplars (*Populus nigra*). The fish community is composed by *Lampetra fluviatilis and L. planeri*, cyprinid fish species, such as *Luciobarbus bocagei, Squalius pyrenaicus, Squalius alburnoides and Pseudochondrostoma polylepis,* and exotic fish species (*Carassius auratus, Gobius lozanoi, Gambusia holbrookii, Lepomis gibbosus, Cyprinus carpio*).

Author(s): Maria Helena Alves (helena.alves@apambiente.pt), Manuela Morais (mmorais@uevora.pt)

26. Erges (PORTUGAL)

Tagus River Basin District

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Segura (15P/02H)
Coordinates (°): -6.983, 39.815 (WGS84)
Catchment area (km²): 981.8
Characteristic channel width: ☐ <1 m ☐1-5 m ☒ >5 m ☐Unknown
River length (km): 144
Elevation range (m a.s.l.): 200 to 600

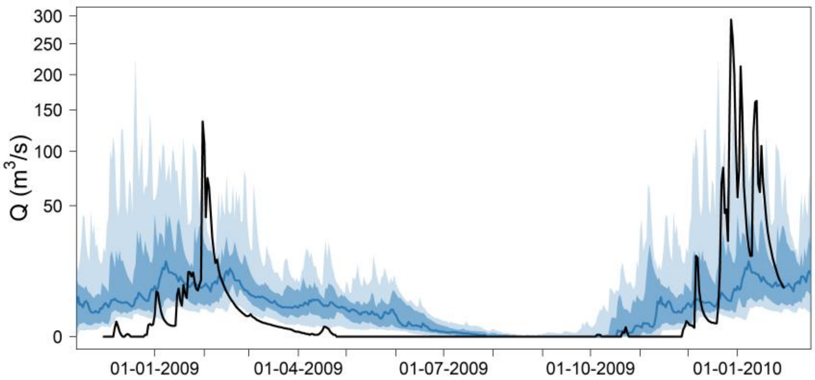
Geology: ☐ Calcareous (limestone, chalk) ☒Silicate (clay, granite)
☐Unknown ☐Other:

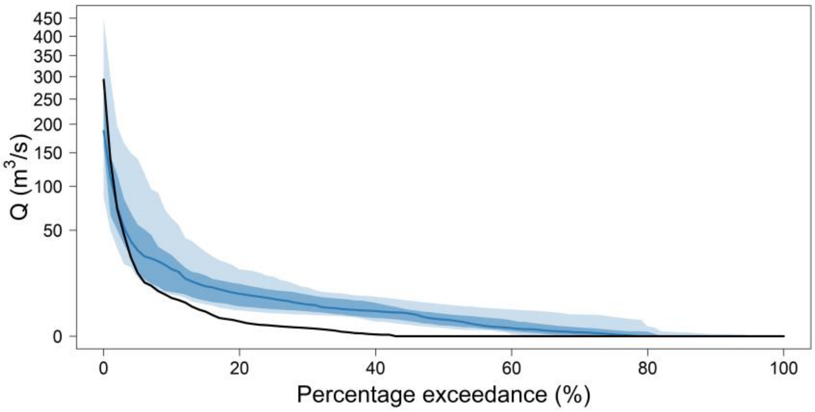
Climate:
Mean annual precipitation (mm/year): 223
Mean annual temperature (°C): 13.7
Köppen class: Hot-summer Mediterranean climate (Csa)

Land use (forest and natural, agricultural, wetlands, artificial): The catchment is dominantly occupied by forest and bushes

Artificial influence: No existence of large dams upstream. Small weirs with very low impact on the flow regime

Rio Erges at Segura (15P/02H) gauging station in spring. Date: 18/04/2017





Hydrographs and flow duration curves of the Rio Erges at Segura gauging station (1984-2011) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Rio Erges at Segura (15P/02H) gauging Station at the beginning of summer. Date: 18/07/2017

Flow metrics (1984-2011)

MAF (m^3/s):	9.79
M_{AMD} (day):	82
CV_{AMD} (day):	0.54
τ0:	21 July
$\tau0_r$:	0.85
k:	0.83
M_{AN} (day):	88
CV_{AN} (day):	0.59

Description and reasons for intermittence

The precipitation at the Segura gauging station presents an annual mean of about 500-600 mm, and is irregularly distributed throughout the year and between years. The number of days with precipitation varies between 50 and 75 days and most rainfall occurs seasonally, from late autumn to early spring. As consequence, there is high variability of the flow regime throughout the year, with long periods without flow, and also of the runoff between dry and wet years. According to the scenarios of climatic changes for 2100, it is expected an increase of 5ºC for the temperature (minimum, average and maximum values), the extension of the summer dry period, the diminution of precipitation, and consequently the aggravation of the temporality.

Spatial pattern: Erges is a naturally Mediterranean intermittent river in its whole length.

Seasonality: No flow during summer and autumn, from July to November, during 1 to 6 months, depending on the characteristics of the hydrological year. In dry years the period with no flow can be longer than 6 months. During the dry season some pools remain in river bed.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☐Interaction with groundwater ☒ Other: the dry season can be longer and include autumn months.

Observations of intermittence

Gauging station(s): The only Portuguese gauging station on the Erges River is Segura (15P/02H). This gauging station has data from 1984 until 2011. The flow regime it is only characterized by the flow data. There is no systematic record of the aquatic state observations.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): Erges River presents flow during late autumn, winter and spring and disconnected pools during summer. At the end of summer until the beginning of autumn the river can became dry at least at certain reaches.

Erges River Basin

The Erges River is a transboundary river shared with Spain. The total catchment area is 1'164 km^2, 540 km^2 in Portugal and 570 km^2 in Spain. The catchment is predominantly mountainous and mostly occupied with forest and bushes. The human pressure is low, namely there is not large dams in the catchment, only small weirs.

Representativeness and ecological value

The Erges River belong to the type Southern Medium-Large Rivers with a drainage basin larger than 100 km^2 and it is classified with good ecological status (December 2018). The river presents a natural flow regime. The channel is dominated by coarse material such as rock, blocks and pebbles. There are some lateral sediment deposits with and without vegetation. In winter, the dominant habitats are runs and deep pools without current or with no apparent current. In spring, it is possible to find some riffles associated to shallower sections with coarser substrate. In summer and early autumn there is no superficial flow, only some pools remain on riverbed during this period.

In what refers to macroinvertebrates, the most representative families of Ephemeroptera are Baetidae (*Baetis* sp.), Caenidae (*Caenis sp*.), Heptagenidae (*Ecdyonurus* sp.) and Ephmerellidae (*Habrophlebia* sp.); Plecoptera are represented Perlodidae; Gastropoda by Ancylidae (*Ancylus* sp.); Coleoptera by Elmidae (*Oulimnius* sp.); and Diptera by Simuliidae and Chironomidade. It is highlighted the high diversity of Diptera observed in the summer pools. Diatom community presents a high diversity, being the more abundant species: *Achnanthidium minutissimum, Cocconeis lineata, Encyonema silesiacum, Fragilaria bidens, Fragilaria capucina var. vaucheriae, Gomphonema pumilum, Gomphonema truncatum, Melosira varians, Navicula notha, Ulnaria acus, Ulnaria biceps.*

The riparian vegetation is in good conditions and presents all the stratus. The dominant trees are ash trees (*Fraxinus angustifolia* subsp. *Angustifolia*), willows (*Salix salviifolia),* poplars (*Populus alba* L.) and alders *Alnus glutinosa*. The dominant shrub is tamujo (*Flueggea tinctoria*), loendro (*Nerium oleander*) and tamargueira (*Tamarix africana)*). The fish community is composed by cyprinid fish species and characterised by a high specific richness and diversity as well as high densities, with relatively high occurrence of endemic species. The fish species with the highest frequency and density is the Bordalo (*Squalius alburnoides*) but the barbles (*Luciobarbus bocagei* and less common *Luciobarbus comizo*) are also dominant. The Erges River is included in a Special Protection Areas (SPAs) (PTZPE0042) according to Habitats Directive due to cegonha-preta (*Ciconia nigra*), among other birds species that feeds from fish, crustaceans and amphibians. It is also possible to find otter.

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27. Terges (PORTUGAL)

Portuguese part of the Guadiana River basin

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Entradas (27I/01H)
Coordinates (°): 37.764; -8.02 (Datum WGS84)
Catchment area (km²): ~ 52
Characteristic channel width: ☐ <1 m ☒ 1-5 m ☐ >5 m ☐Unknown
River length (km): 140
Elevation range (m a.s.l.): 168 to 264

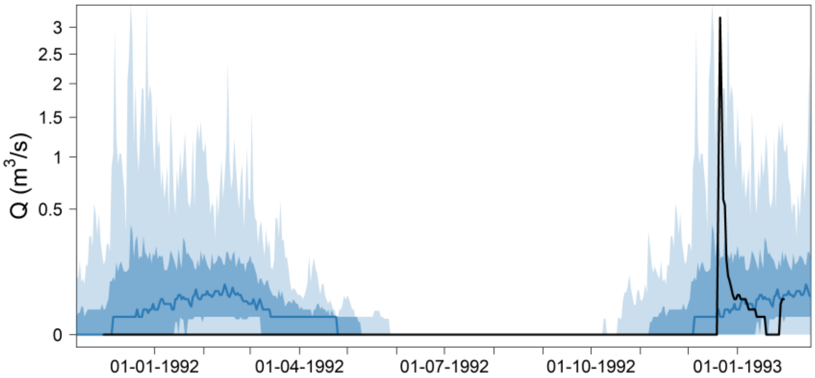
Geology: ☒ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒Other: Sedimentary

Climate:
Mean annual precipitation (mm/year): 485
Mean annual temperature (°C): 18.6
Köppen class: Hot-summer Mediterranean climate (Csa)

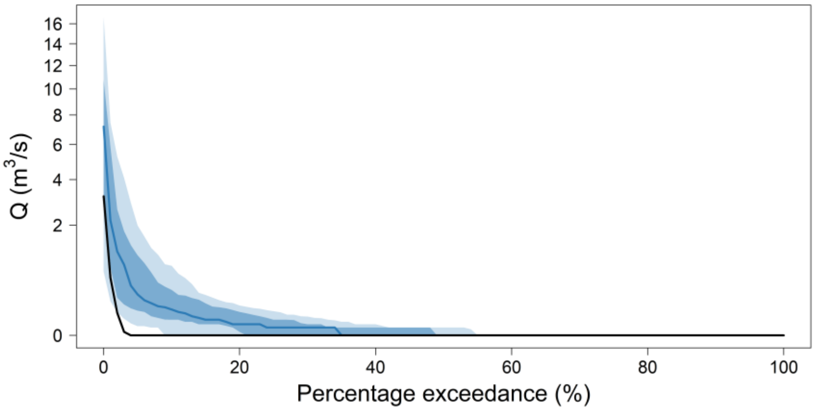
Land use (forest and natural, agricultural, wetlands, artificial): Forest and natural vegetation (~ 5%); agriculture (~ 92%); urban (< 3%)

Artificial influence: Minor

Lower section of Terges River near gauging station in winter with flowing conditions. Date: 27/02/2019



Summer pools in a lower section of Terges River. Date: 27/02/2019



Hydrographs and flow duration curves of the Terges at the gauging station Entradas 27I/01H (1971-2018) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Flow metrics (1971-2018)

MAF (m^3/s):	0.17
M_{AMD} (day):	216
CV_{AMD} (day):	0.24
$\tau 0$:	4 March
$\tau 0_r$:	0.62
k:	0.66
M_{AN} (day):	241
CV_{AN} (day):	0.24

Description and reasons for intermittence

The Terges River catchment is composed of siliceous and metamorphic rocks with shallow overlying soils. Maximum mean monthly temperature is 34°C (July), minimum is 5°C (January) and mean annual precipitation is <500 mm, irregularly distributed throughout the year and among different years. Heavy storms with torrential regime may cause the river to flood. Flash floods during spring recede much faster than those in winter, and discharge can return to baseflow in a few days. This precipitation regime results in a natural irregular river flow regime with the lowest discharges usually recorded in summer, with absence of precipitation.

Spatial pattern: The Terges River is a Mediterranean river naturally intermittent in its whole length.

Seasonality: Flow ceases in its whole length from late spring (April/May) to autumn (October/November) every year.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☐Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): There is only one gauging station located in the lower section of Terges River.

Flow/aquatic state observations (e.g. “flow”, “disconnected pools”, “dry bed”): Terges is an intermittent river in its whole length. Each year, during summer the channel becomes fragmented into a series of discontinues pools. Most pools are small and shallow (<50 m^2 in area and <50 cm deep) and persist in solid rock basins, having little or no contact with subsurface flow. During summer in the lower section of the river, the streambed remains completely dry and is often occupied by grazing animals.

Ecological quality

The Terges river basin is sparsely populated with 3 WWTPs that serve ~ 1500 inhabitants equivalent. The river flows in a basin dominated by pasture, and by extensive and intensive agriculture with livestock occupation. Consequently, the river presents an accentuated degradation such as, eroding banks, sand and organic matter depositions areas, filamentous algae and cyanobacteria in standing water habitats, in the margins, and in the summer pools.

The riparian vegetation presents accentuated evidences of degradation mainly in the lower section (near the gauging station). Potentially and in less degraded sections, the arboreal stratum is dominated by ash trees (*Fraxinus angustifolia*) *Nerium oleander*, *Tamarix africana*, *Olea europea* var. *sylvestris*, with a shrub structure naturally discontinuous.

Diatom community is dominated by ubiquitous species such as, *Eolimna subminuscula*, *Gomphonema parvulum*, *Navicula veneta.*

Macrophytes are characterized by a high number of terrestrial taxa, grasses, hydrophytes and helottes and nitrophilous species. It is also worth to mention the great abundance of *Typha angustifolia*, *Cyperus longus*, and *Scirpoides holoschoenus.*

In what refers to macroinvertebrates, the most representative taxa belong to Chironomidae, Dysticidae, Physidae and Oligochaeta, either in spring flow conditions or in summer pools.

In fact, all these ecological characteristics indicate a degraded system, with an ecological status less than good.

Author(s): Manuela Morais (mmorais@uevora.pt), Alice Fialho (alice.fialho@apambiente.pt), Maria Helena Alves (helena.alves@apambiente.pt)

28. Vascão (PORTUGAL)

Portuguese part of the Guadiana River basin

Characteristics from the catchment at: ☐ the outlet
X the gauging station: Vascão (28L/02H)
Coordinates (°):-7.579, 37.52 (WGS84)
Catchment area (km²): ~ 410
Characteristic channel width: ☐ <1 m ☒ 1-5 m ☐ >5 m ☐Unknown
River length (km): ~ 200
Elevation range (m a.s.l.): 49 to 425

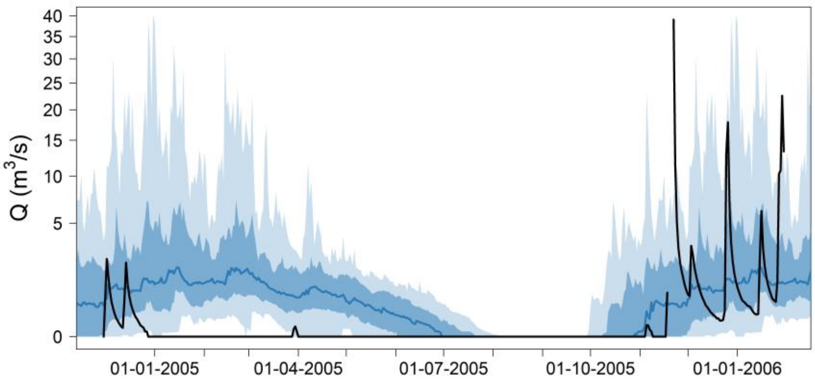
Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite) ☐Unknown ☒Other: Sedimentary

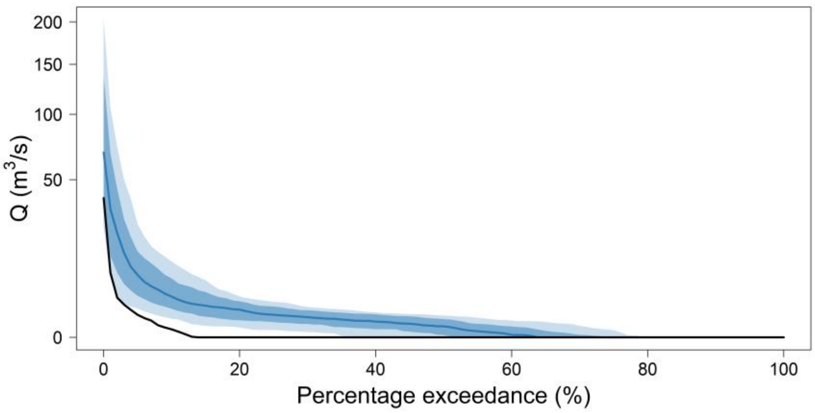
Climate:
Mean annual precipitation (mm/year): 519
Mean annual temperature (°C): 18.6
Köppen class: Hot-summer Mediterranean climate (Csa)

Land use (forest and natural, agricultural, wetlands, artificial): Forest and natural vegetation (~ 78%), agriculture (~ 20%), urban (< 2%)

Artificial influence: Minimal

Lower section of Vascão River near Vascão (28L/02H) gauging station in winter, with flowing conditions. Date: 27/02/2019





Hydrographs and flow duration curves of the Vascão at Vascão (28L/02H) gauging station (1950-2016) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Dry river bed in a lower section of Vascão River, near Vascão (28L/02H) gauging station, in summer conditions. Date: 06/2018

Flow metrics (1950-2016)

MAF (m^3/s):	2.77
M_{AMD} (day):	113
CV_{AMD} (day):	0.46
$\tau 0$:	5 July
$\tau 0_r$:	0.64
k:	0.76
M_{AN} (day):	125
CV_{AN} (day):	0.56

Description and reasons for intermittence

The Vascão river catchment is composed of siliceous and metamorphic rocks with shallow overlying soils. Maximum mean monthly temperature is 34°C (July), minimum is 5°C (January) and mean annual precipitation is about 500 mm, irregularly distributed throughout the year and among different years. Most rainfall occurs seasonally, from late autumn to early spring. Heavy storms may cause the river to flood. Flash floods during spring recede much faster than those in winter, and discharge can return to baseflow in a few days. This precipitation regime results in a natural irregular river hydrology with lowest discharge usually recorded during summer, when precipitation drops to zero.

Spatial pattern: The Vascão River is a Mediterranean river naturally intermittent in its whole length.

Seasonality: Flow ceases in its whole length during summer, every year; and only starts to flow after the first rain in autumn. Usually flowing conditions are observed from November to May.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☐Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): There is only one gauging station located in the lower section of Vascão River.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): Like almost all rivers in the south of Portugal, Vascão is an intermittent river in its whole length. Each year, during summer the channel becomes fragmented into a series of isolated pools. Most pools are small and shallow (<50 m^2 in area and <50 cm deep) and persist in solid rock basins, having little or no contact with subsurface flow.

Representativeness and ecological value

The Vascão River catchment is very sparsely populated with 7 WWTPs for a total of 1591 inhabitants' equivalent. The river (~ 455 km^2 at its mouth) flows in a very preserved forest catchment integrated in the Guadiana Natural Park and was classified as a Ramsar Site due to its ecological integrity. It is also the largest river in Portugal without artificial barriers, such as dams.

The structure of the riparian vegetation is dominated by shrubs naturally discontinuous or narrow. The arboreal stratum is dominated by ash trees (*Fraxinus angustifolia*), *Nerium oleander*, *Tamarix africana*, *Olea europea* var. *sysvestris*.

The river presents the highest concentrations of the critically endangered freshwater fish Saramugo (*Anaecypris hispanica*).

Diatom community is dominated by alkaline and heavily mineralized species such as *Achnanthes lanceolata* ssp. *frequentissima*, *Amphora pediculus*, *Navicula gregaria*, *Cocconeis pediculus*, *Nitzschia inconspicua*, among others.

Macrophytes are characterized by high species richness, high number of terrestrial taxa, grasses, hydrophytes and nitrophilous species. It is also worth to mention the great abundance and frequency of *Ranunculus peltatus* ssp. *saniculifolius* and *Ranunculus peltatus* ssp. *peltatus*.

In what refers to macroinvertebrates, the most representative families of Ephemeroptera are Baetidae (*Baetis* sp.), Caenidae (*Caenis* sp.), Heptagenidae (*Ecdyonurus* sp.) and Ephmerellidae (<u>Habrophlebia</u> sp.); Plecoptera is represented by Leuctridae and Perlidae (*Isoperla* sp.); Gastropoda by Ancylidae (*Ancylus* sp.); Coleoptera by Elmidae (*Oulimnius* sp.); and Diptera by Limoniidae, Ceratopogonidae and Simuliidae. It should be highlighted the high diversity of Diptera observed in the summer pools.

Author(s): Manuela Morais (mmorais@uevora.pt), Alice Fialho (alice.fialho@apambiente.pt), Maria Helena Alves (helena.alves@apambiente.pt)

29. Moravica (SERBIA)

North-East Serbia, Vojvodina province, Black Sea drainage basin

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Moravica at Vatin
Coordinates (°): 45.231504, 21.249142 (WGS84)
Catchment area (km²): 432
Characteristic channel width: ☐ <1 m ☐1-5 m ☒ >5 m ☐Unknown
River length (km): 17.4
Elevation range (m a.s.l.): 74 to 78

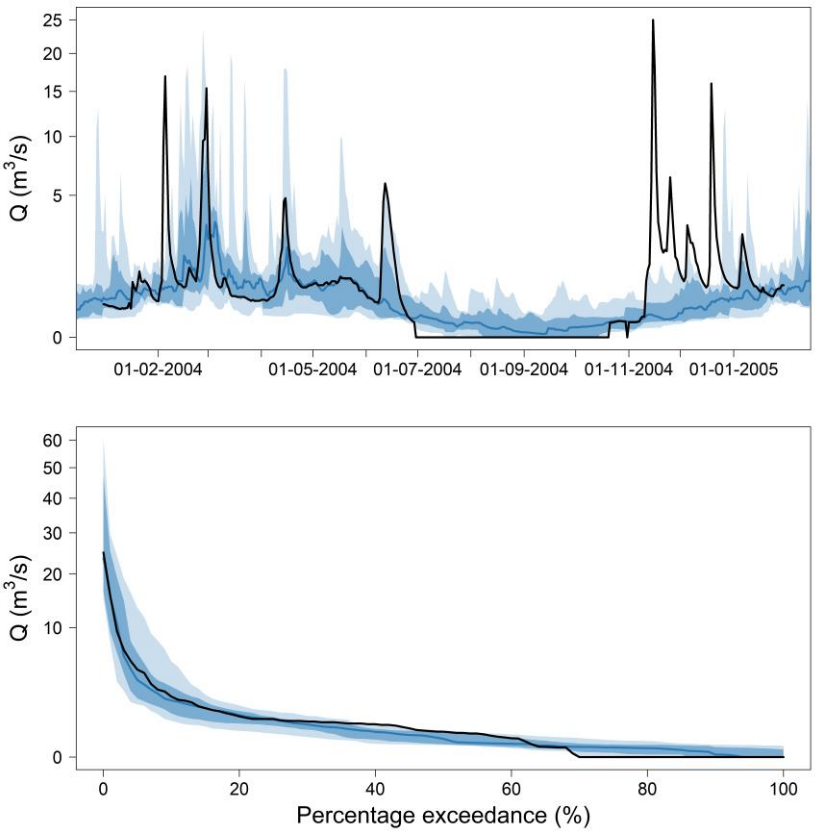
Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒ Other: Sedimentary

Climate:
Mean annual precipitation (mm/year): 600
Mean annual temperature (°C): 11
Köppen class: Humid subtropical climate (Cfa)

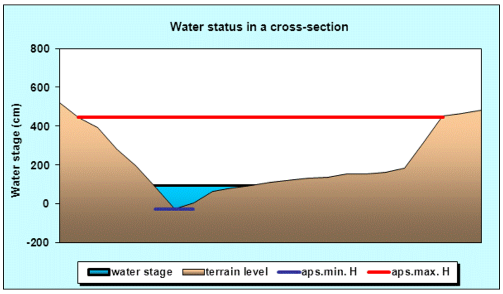
Land use (forest and natural, agricultural, wetlands, artificial): Agricultural (100%)

Artificial influence: The river is channelled and it flows into the Danube-Tisa-Danube Hydro system

The Moravica River near Vatin, 27/08/2006 (https://commons.wikimedia.org/wiki/File:Moravica_river_near_Vatin,_Serbia.jpg)



Hydrographs and flow duration curves of the Moravica at Vatin (2004-2015) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale



Cross-section of the Moravica River at Vatin (http://www.hidmet.gov.rs)

Flow metrics (2004-2015)

MAF (m^3/s):	1.34
M_{AMD} (day):	34
CV_{AMD} (day):	1.20
τ0:	9 August
$τ0_r$:	0.87
k:	0.8
M_{AN} (day):	35
CV_{AN} (day):	1.18

Description and reasons for intermittence

Moravica River is a channeled watercourse in the border region between Romania and Serbia. It flows into the Danube - Tisa - Danube Hydro system network. The surrounding area is an agricultural land. The amount of water in Moravica is very variable depending on the time of year. The largest amount of water is in the spring period, which is the result of snowmelt from the Carpathian Mountains and from precipitation. During the summer period, the water level decreases significantly and in some parts it dries.

Spatial pattern: Intermittent in the whole course.

Seasonality: Flow ceases mainly in the end of summer and in autumn.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☒Water management
☒Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): There is only one gauging station on river Moravica. It is located near village Vatin, 16 km from the confluence. The gauging station is managed by the Republic Hydrometeorological Service of Serbia. Records of water levels and flows starts form 1921. Flow intermittence is observed at this gauging station, and also visually by observing historical imagery in Google Earth.

Flow/aquatic state observations (e.g. “flow”, “disconnected pools”, “dry bed”): There is no available information on aquatic states of this river besides historical imagery from the Google Earth. From the Google Earth imagery from September 2017, “disconnected pools” and “dry bed” state can be noticed in all part of the river.

Author(s): Atila Bezdan (bezdan@polj.uns.ac.rs)

30. Visočica (SERBIA)

East Serbia, Black Sea drainage basin

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Visočica at Braćevci
Coordinates (°): 43.1241, 22.8667 (WGS84)
Catchment area (km²): 820
Characteristic channel width: ☐ <1 m ☐1-5 m ☒ >5 m ☐Unknown
River length (km): 71
Elevation range (m a.s.l.): 600 to 1640

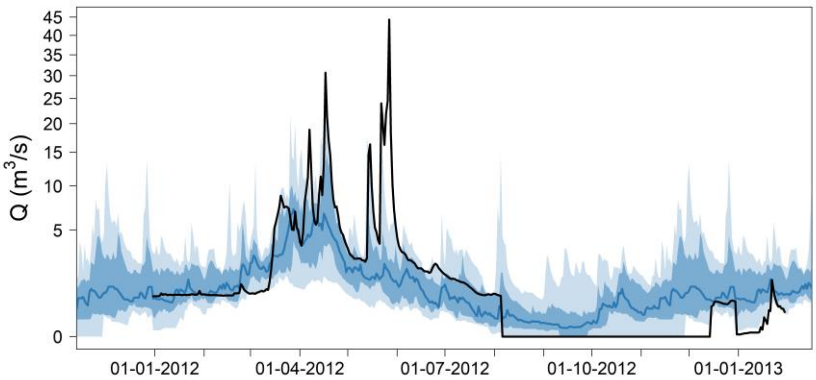
Geology: ☒ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒Other: Sedimentary

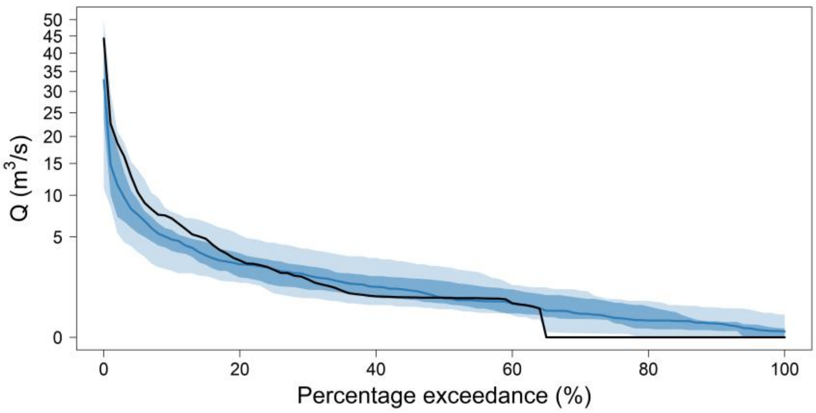
Climate:
Mean annual precipitation (mm/year): 600
Mean annual temperature (°C): 10.7
Köppen class: Temperate oceanic climate (Cfb)

Land use (forest and natural, agricultural, wetlands, artificial): Forest and natural (90%), agricultural and artificial (10%)

Artificial influence: 90% of the river flow is diverted into the accumulation lake for the hydroelectric power plant

Photo taken at Visočka Ržana, on 16/08/2015, 43.1544N, 22.8140E (https://maps.google.com/maps/contrib/100143762123635266109/photos)





Hydrographs and flow duration curves of the Visočica at Braćevci (2004-2015) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Photo taken at Akleštica, on 13/05/2007, 43.2067N 22.7379E (https://maps.google.com/maps/contrib/103470330572479619688/photos)

Flow metrics (2004-2015)

MAF (m^3/s):	2.19
M_{AMD} (day):	31
CV_{AMD} (day):	1.66
τ0:	14 August
$τ0_r$:	0.54
k:	0.82
M_{AN} (day):	31
CV_{AN} (day):	1.66

Description and reasons for intermittence

Visočica is a river that passes through easternmost Serbia and westernmost Bulgaria, a right tributary of the Temštica. It belongs to the Black Sea drainage basin. The river begins at a height of 1640 m in the Berovo Mountain, part of the Balkan Mountains, immediately and east of the Serbia-Bulgaria border. In the 90' the hydroelectric power plant "Pirot" was constructed and the flow from the river Visočica is diverted to the accumulation lake Zavoj. After that, the river lost 90% of its flow.

Spatial pattern: Intermittent in the middle and upstream part.

Seasonality: Flow ceases mainly in the end of summer and in autumn.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☒Water management
☐Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): There is only one gauging station on river Visočica. It is located near village Braćevci, 43.4 km from the confluence, in the middle-upper part of the river. The gauging station is managed by the Republic Hydrometeorological Service of Serbia. Records of water levels and flows starts form 1963. Flow intermittence is observed at this gauging station, and also visually by observing historical imagery in Google Earth.

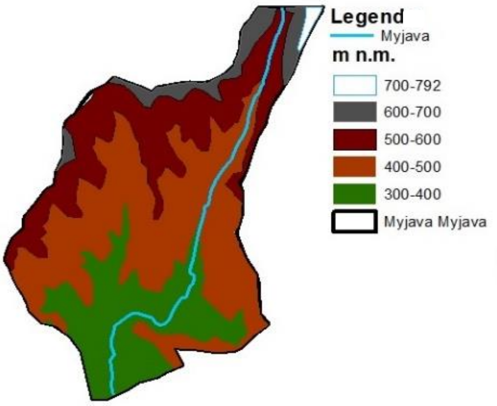
Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): There is no available information on aquatic states of this river besides historical imagery from the Google Earth. From the Google Earth imagery from August, "disconnected pools" can be noticed in all part of the river and imagery from October 2012 shows "disconnected pools" and even "dry bed" state in some parts of the river from 35 km and upstream.

Author(s): Atila Bezdan (bezdan@polj.uns.ac.rs)

31. Myjava (SLOVAKIA)

Trenčiansky county, Senica district, River basin Morava

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Myjava at Myjava-Myjava
Coordinates (°): 48.7611, 17.5672 (WGS84)
Catchment area (km²): 33.09
Characteristic channel width: ☐ <1 m ☒ 1-5 m ☐ >5 m ☐Unknown
River length (km): 10.8
Elevation range (m a.s.l.): 300 to 792



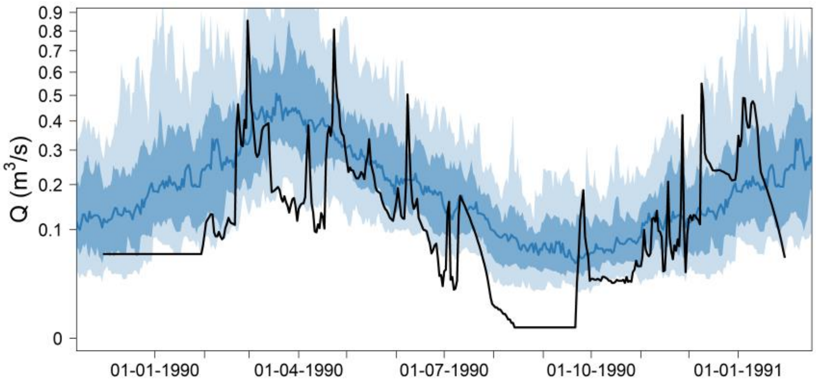
Myjava River (altitudinal zones)

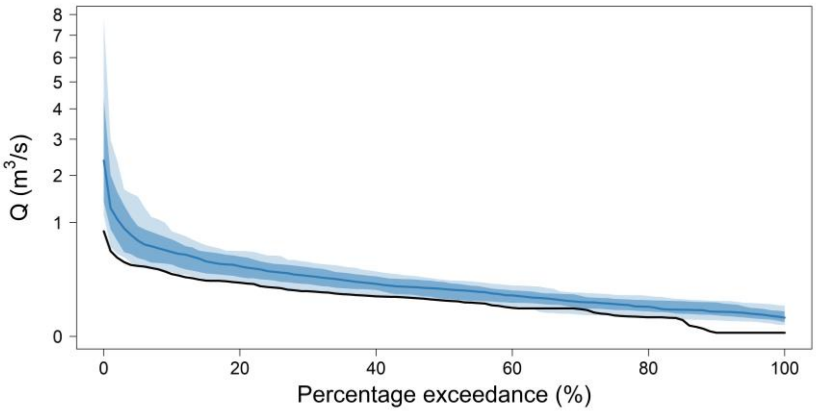
Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒Other: Cambisols, Luvisols

Climate:
Mean annual precipitation (mm/year): 650-700
Mean annual temperature (°C): 8.2
Köppen class: Warm-summer humid continental climate (Dfb)

Land use (forest and natural, agricultural, wetlands, artificial): Arable land (25%), grass (19%), coniferous forests (7%), deciduous forests (28 %), mixed forests (5%), bushes (8%), bare soil (<1%), urbanized areas (8%), water (<1%)

Artificial influence: Unknown





Hydrographs and flow duration curves of the Myjava at Myjava-Myjava (1973-2012) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Myjava River (https://sk.wikipedia.org/wiki/Myjava_(rieka)#/media/File:Myjava_river_3.jpg) (location: 48°37′44″ 16°57′35″)

Flow metrics (1973-2012)

MAF (m^3/s): 0.28

M_{AMD} (day): 1.00
CV_{AMD} (day): 6.16
$\tau 0$: 21 October
$\tau 0_r$: 0.41
k: 0.89
M_{AN} (day): 1
CV_{AN} (day): 6.16

Description and reasons for intermittence

Intermittent rivers are rare in Slovakia. However, more zero-flow events were recorded after the year 1980 than before, (Figure 2). The catchments of intermittent rivers differ by elevation and by location and the intermittence is mostly due to dry climatic periods. This is in connection with the land use, soil types as well (Figure 1).

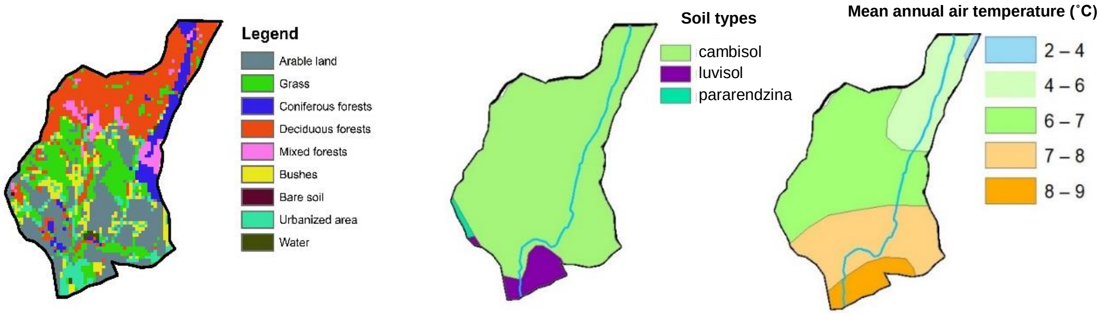


Figure 1: Land use, soil types and mean annual air temperature (1980-2013) at the Myjava River basin

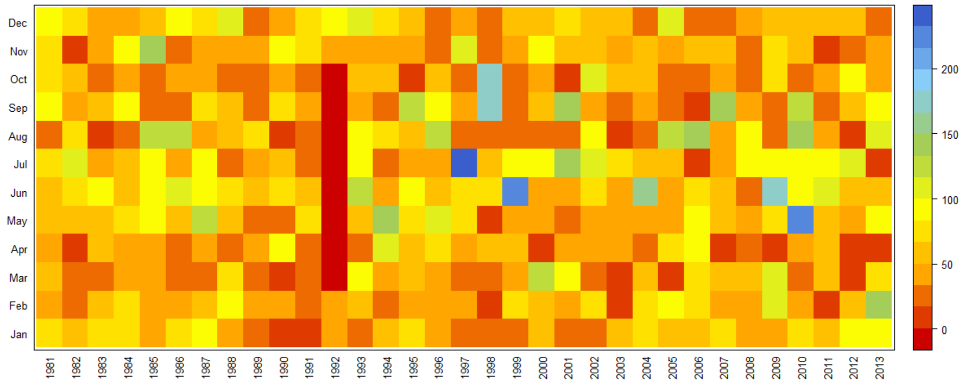


Figure 2: Patterns of mean monthly precipitation totals during the period 1980-2013 in the Myjava River basin

Spatial pattern: Intermittence observed at the outlet.

Seasonality: The Myjava River belongs to the middle warm mountainous climate and has predominant rainfall-snowmelt runoff regime, with the highest mean monthly discharges in February and March and the lowest during the autumn months September-October and winter months December–January. The concentration of the zero-flow events mostly after the year 1980 is in agreement with longer droughts in this period due to increasing mean annual air temperature up to +2°C and increasing potential evapotranspiration.

Driver(s): ☒ Summer dry period ☐ Freezing/snow ☐Water management
☐Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): The intermittence was observed at the gauging station Myjava-Myjava.

Flow/aquatic state observations (e.g. “flow”, “disconnected pools”, “dry bed”): No observation available.

Author(s): Silvia Kohnova (silvia.kohnova@stuba.sk)

32. Búger (SPAIN)

Tributary of Sant Miquel River basin

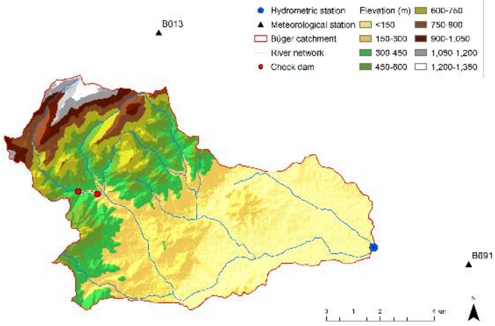
Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Búger
Coordinates (°): 39.7521, 2.9787 (WGS84)
Catchment area (km²): 68.2
Characteristic channel width: ☐ <1 m ☐1-5 m ☒ >5 m ☐Unknown
River length (km): 21.6
Elevation range (m a.s.l.): 55 to 1360

Geology: ☐ Calcareous (limestone, chalk) ☐ Silicate (clay, granite)
☐ Unknown ☒ Other: Dolomites and limestone at headwater and silt, clays and gravels at the floodplain

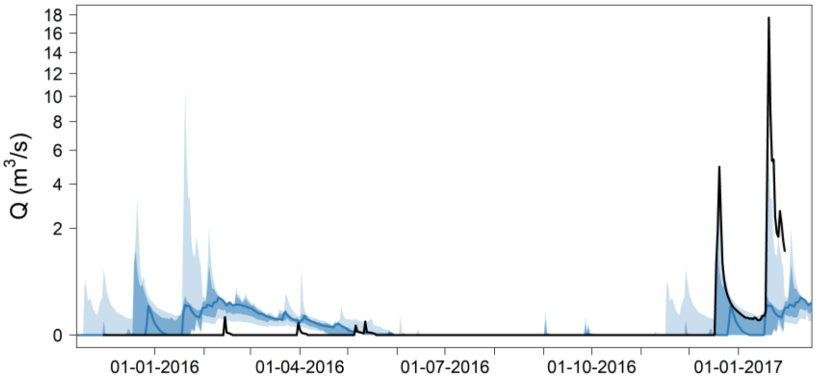
Climate:
Mean annual precipitation (mm/year): 810
Mean annual temperature (°C): 14.4 (B013), 17.6 (B691)
Köppen class: Hot-summer Mediterranean climate (Csa)

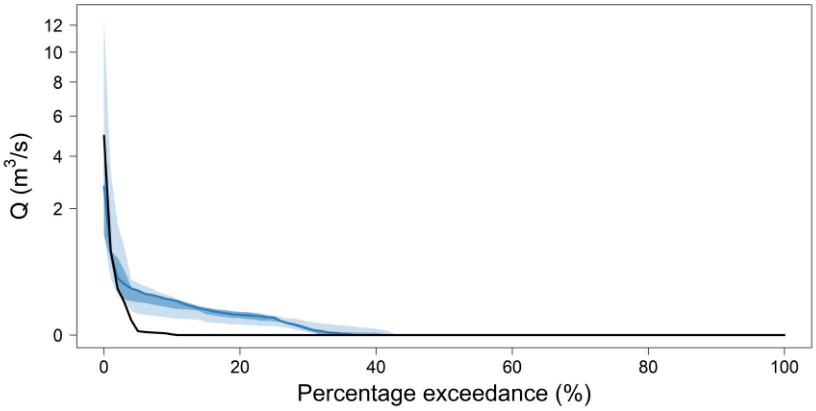
Land use (forest and natural, agricultural, wetlands, artificial): Agricultural (44%), forests (35%), sparsely vegetated areas (10%), olive groves (9%), natural grasslands (1%) and urban (1%)

Artificial influence: check dams and terraces



Study area. Búger River catchment with hydrometric station, meteorological stations, check dams and river network





Hydrographs and flow duration curves of the Búger River basin (2013-2017) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Downstream view of Búger gauging station during a flood event on 20th January 2017. Photo: Joan Estrany

Flow metrics (2013-2017)

MAF (m^3/s):	0.07
M_{AMD} (day):	171
CV_{AMD} (day):	0.41
$\tau 0$:	2 February
$\tau 0_r$:	0.67
k:	0.73
M_{AN} (day):	277
CV_{AN} (day):	0.20

Description and reasons for intermittence

The natural flow regime of the Búger River is characterized by a high intra- and inter-annual variability. Runoff response is generated when catchment water reserves are full, which starts normally at middle - late autumn.

Spatial pattern: Headwaters are ephemeral due to a karstic geological composition (Tramuntana Range). The middle part of the catchment has an intermittent behaviour as flows over impervious material (Cretaceous marls). The lower part of the catchment is ephemeral due to the Búger River flows over alluvial materials.

Seasonality: Wet and dry periods can be identified. The wet season allows a continuous runoff and baseflow generation from November to May, where November, December and May presented a higher monthly variability in their runoff contribution. Largest runoff contribution at monthly scale were January, February and December. The 86% of the runoff yield was generated during those last three months. The biggest flood occurred in 21/01/17 and the runoff generated was the 79% of the study period (2012-2017). The dry period occurred between May to October where the channel is mostly dry. Flood events may occur but never in July and August.

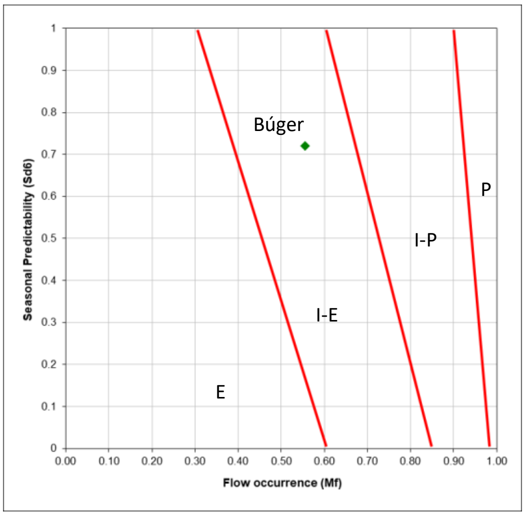
Driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☒Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): Búger River gauging station is one of the six gauging stations of the Sant Miquel River catchment (151 km^2; http://medhycon.uib.cat/study-areas.html). Under a nested approach, these stations have a catchment size from 3 to 145 km^2. Since 2012, discharge, dissolved and suspended sediment concentrations, precipitation, temperature and soil humidity are recorded at 15 minutes step at each gauging station.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): during fieldwork visits under baseflow and flood conditions, water and sediment samples are collected to calibrate the stage-discharge rating curve as well as the suspended sediment concentrations. Flow observations (i.e., flow, pools or dry) in different hotspot sites are carried out.

Flow permanence – Seasonal predictability



According to the hydrological regime classification proposed by Gallart *et al*. (2012), Búger River can be classified as an intermittent-ephemeral regime. This classification was elaborated using flow permanence (Mf) and seasonal predictability (Sd6) of the zero-flow month. P (Permanent), I-P (Intermittent-pools), I-E (Intermittent-ephemeral), E (Episodic-ephemeral).

Gallart *et al.* (2012). A novel approach to analyzing the regimes of temporary streams in relation to their controls on the composition and structure of aquatic biota. Hydrology and Earth System Sciences, 16(9), 3165-3182.

Author(s): Joan Estrany (joan.estrany@uib.cat), Josep Fortesa (josep.fortesa@uib.cat)

33. Daró (SPAIN)

Gavarres massif to the Empordà plain (Catalonia)

Characteristics from the catchment at: ☒ the outlet
☐ the gauging station
Coordinates (°): 42.037586, 3.118526 (WGS84)
Catchment area (km²): 320
Characteristic channel width: ☐ <1 m ☒1-5 m ☐ >5 m ☐Unknown
River length (km): 35
Elevation range (m a.s.l.): 4 to 435

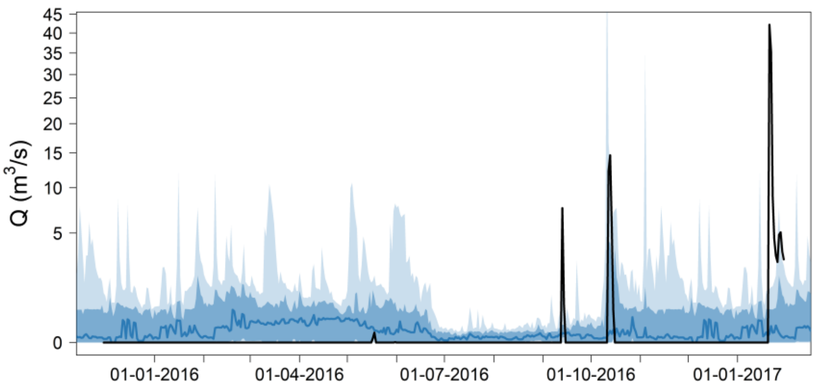
Geology: ☒ Calcareous (limestone, chalk) ☒Silicate (clay, granite)
☐Unknown ☐Other:

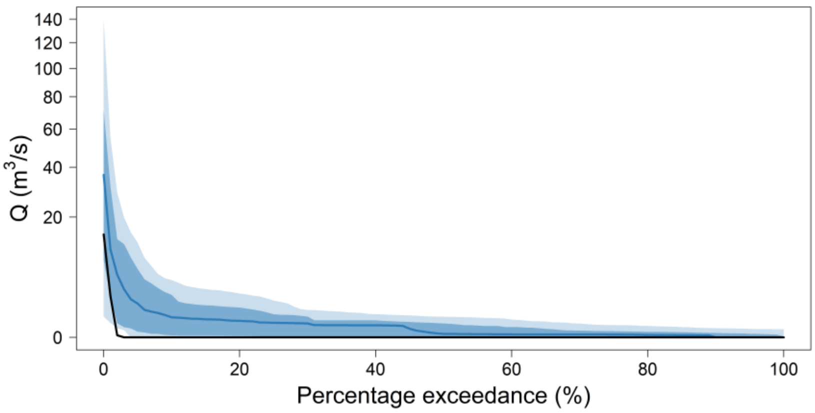
Climate:
Mean annual precipitation (mm/year): 710
Mean annual temperature (°C): 15
Köppen class: Hot-summer Mediterranean climate (Csa)

Land use (forest and natural; agricultural; wetlands; artificial): Forest in the headwaters; agricultural and forest in the down waters

Influence: No regulation, groundwater abstractions in the middle part

Middle section of the Daró River near Sant Sadurní in flowing phase. Street View photograph; date: 04/2013; coordinates: 41.953682, 3.031504





Hydrographs and flow duration curves of the Daró at Serra de Daró (2001-2017) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Lower section of the Daró River near Serra de Daró in disconnected pools phase. Google Earth photograph; date: 23/10/2015; coordinates: 42.025029; 3.070213

Flow metrics (2001-2017)

MAF (m^3/s):	1.19
M_{AMD} (day):	66
CV_{AMD} (day):	1.13
$\tau 0$:	23 December
$\tau 0_r$:	0.50
k:	0.74
M_{AN} (day):	134
CV_{AN} (day):	1.17

Description and reasons for intermittence

The temporariness of flow is a natural characteristic of this river system, but the presence of permanent pools during dry periods is necessary for the survival or many species, particularly fishes. The testimony of aged inhabitants as well as the presence of old mills and washing sinks show that river flow decreased in the last decades. This is to be mainly attributed to the role of the strong increase of dense and unmanaged forest cover after land abandonment, as reported in other examples in the Iberian Peninsula.

The Daró River is representative of the hydrology in the County named l'Empordà. This is a low plain surrounded by low mountain areas, mainly made of low permeability Palaeozoic rocks; rivers are rather flashy but the plain has sustained high groundwater levels.

Spatial pattern: Intermittent in the whole course, mainly in the middle part.

Seasonality: Flow ceases every year but some isolated pools remain. Driest season is summer but flow may cease in any season.

Main driver(s): ☒ Summer dry period ☐Freezing/snow ☐Water management
☒Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): There are two gauging stations in the Daró River: at La Bisbal d'Empordà and at Serra de Daró, both managed by the Catalan Water Authority (ACA). Nevertheless, the first one was designed for early flood warning and do not provide reliable readings of low flows.

Flow/aquatic state observations (e.g. "flow", "disconnected pools" and "dry bed"): Methodology and work developed within the LIFE TRIVERS project allowed gathering information on the regime of the Daró River at three river sections, paying attention to the temporal patterns of occurrence of the three main phases of the river regime relevant for aquatic life: flow, isolated pools and dry stream bed. This information was obtained from interviews, in situ observations and the interpretation of aerial or terrestrial series of photographs (Gallart *et al.,* 2017).

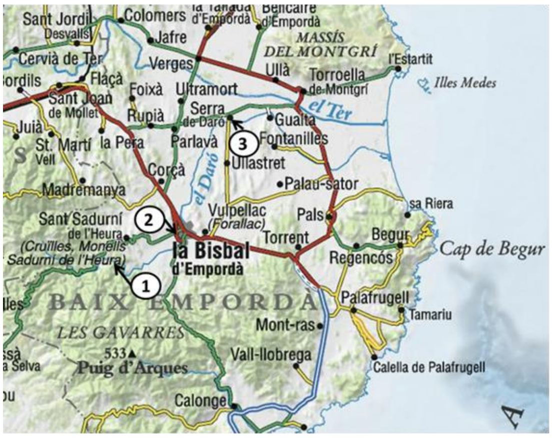
Gallart *et al*. (2017). TREHS: An open-access software tool for investigating and evaluating temporary river regimes as a first step for their ecological status assessment. Science of the Total Environment, 607, 519-540.

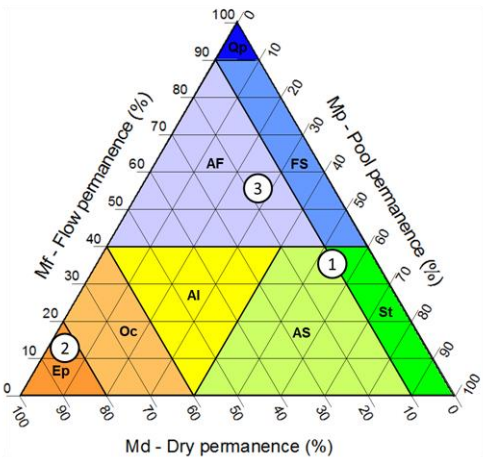
Ecological value

The headwaters of the Daró River is an area of high ecological value; it is a natural fluvial preserved area and is part of the network of reference rivers in Catalonia. Among other species, there are populations of the protected three-spined stickleback fish (*Gasterosteus aculeatus).*

Temporary regime assessment

The triangular diagram on the right side represents the regime assessed in the three river sections shown on the map on the left side. The three coordinates represent the permanence (relative frequency) of the three aquatic phases; *flow*, *isolated pools* and *dry stream bed*. The regimes shown in the triangular plot are: Quasi-perennial (Qp), Fluent-Stagnant (FS), Alternate-Fluent (AF), Stagnant (St), Alternate-Stagnant (AS), Alternate (Al), Occasional (Oc), Episodic (Ep). The episodic character of the river at the section 2 is partly due to the thickness of the alluvial deposits that transmit the flow and prevent the occurrence of surface water.





Author(s): Francesc Gallart (francesc.gallart@idaea.csic.es)

34. Matarranya (SPAIN)

from the Els Ports massif to the vicinity of the Ebro River

Characteristics from the catchment at: ☒ the outlet
☐ the gauging station:
Coordinates (°): 41.195118, 0.171441 (WGS84)
Catchment area (km²): 1’260
Characteristic channel width: ☐ <1 m ☐1-5 m ☒ >5 m ☐Unknown
River length (km): 110
Elevation range (m a.s.l.): 212 to 1’062

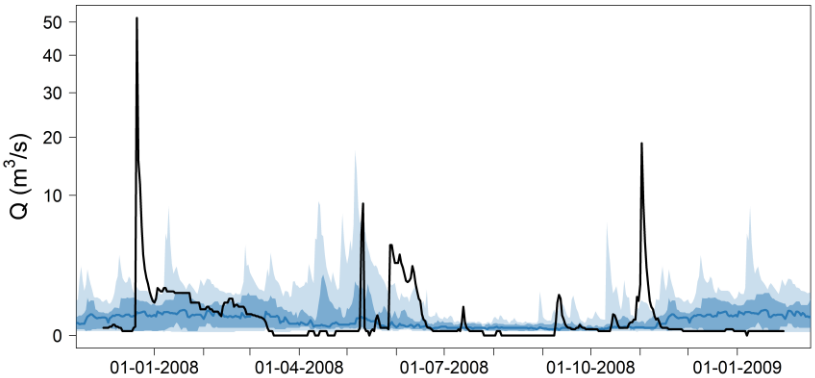
Geology: ☒ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☐Other:

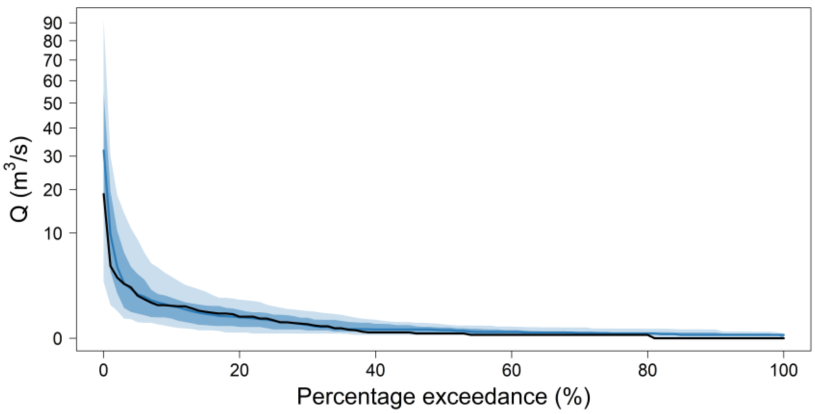
Climate:
Mean annual precipitation (mm/year): ~ 600
Mean annual temperature (°C): N.A.
Köppen class: Hot-summer Mediterranean climate (Csa)

Land use (forest and natural; agricultural; wetlands; artificial): Forest in the headwaters; irrigated and dry farming in the down waters

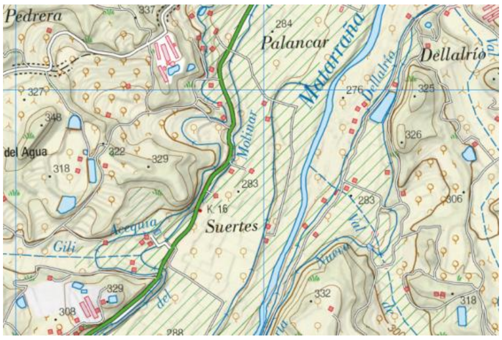
Influence: Flow is regulated by the Pena reservoir (17.8 hm^3), two small reservoirs (1-2 hm^3) and numerous small irrigation ponds

Lower section of the Matarranya River near Nonaspe in disconnected pools phase. Street View photograph; date: 06/2012; coordinates: 41.211501, 0.248609





Hydrographs and flow duration curves of the Matarrananya at Fabara (1994-2013) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale



Map of the lower section of the Matarranya River near Maella, showing the irrigation canals (acequia) and the abundant irrigation ponds. Map grid: 1 km. Source: IGN. Coordinates: 41.106737, 0.131871

Flow metrics (1994-2013)

MAF (m^3/s):	0.85
M_{AMD} (day):	8
CV_{AMD} (day):	2.29
τ:	23 December
τ_r:	0.30
k:	0.71
M_{AN} (day):	12
CV_{AN} (day):	2.3

Description and reasons for intermittence

This river is naturally perennial but it is subject to very important water abstractions mainly for irrigation. The Pena reservoir (1930) strongly modifies the regime because it retains water in winter and releases it in summer for irrigation. Downstream there are a few small reservoirs, a large number of small irrigation ponds and several irrigation canals. The present river regime started in 1994 when a change in the relationship between observed and simulated flows occurred. Subsurface water flow in the thick alluvial deposits of gravels and cobbles is permanent and allows the occurrence of water pools after the cessation of surface flow. The presence of these permanent pools during dry periods is necessary for the survival or many species, particularly fishes. When river flow ceases, thick alluvial deposits transmit water that outcrops in some places as isolated pools.

Spatial pattern: Intermittent in the middle and lower sections. Perennial in the headwaters.

Seasonality: Flow ceases most years but some isolated pools remain. Driest season is summer but flow may cease in any season for ponding and in summer water flows in irrigation canals instead of in the river.

Drivers: ☐ Summer dry period ☐Freezing/snow ☒Water management
☐Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging stations: There are nine gauging stations in the Matarranya River, eight in the headwaters of the main stream and its tributaries, and one downstream at Fabara, near its confluence with its main tributary, the Algars River. This last station is located in a 90 m wide stream channel with thick alluvium. The weir was designed to intercept the subsurface flow within the alluvium, which is therefore measured as surface flow. Nevertheless, the abundant mobile alluvial elements make difficult the maintenance of the low flows lateral weir. All these stations are managed by the Ebro River Basin Authority (CHE).

Flow/aquatic state observations (e.g. "flow", "disconnected pools" and "dry bed"): Methodology and work developed within the LIFE TRIVERS project allowed gathering information on the regime of the Matarranya river near the gauging station at Fabara, paying attention to the temporal patterns of occurrence of the three main phases of the river regime relevant for aquatic life: flow, isolated pools and dry stream bed. This information was obtained from interviews, in situ observations and the interpretation of aerial or terrestrial series of photographs (Gallart *et al.,* 2017).

Gallart *et al*. (2017). TREHS: An open-access software tool for investigating and evaluating temporary river regimes as a first step for their ecological status assessment. Science of the Total Environment, 607, 519-540.

Ecological value

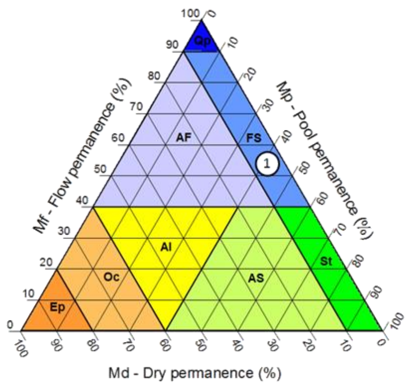
The Matarranya River is the main collector of the waters fed by the southwestern edge of the Iberian range, a water rich massif that intercepts the moisture coming from the Mediterranean to the inland, and irrigates the semiarid southern edge of the Ebro depression. Its main ecological value is the high richness of fish species (e.g. Grossman *et al.,* 1987) that suffer from the deterioration of the habitat (Quirós and Vinyoles, 2016).

Grossman *et al*. (1987). Microhabitat use in a Mediterranean riverine fish assemblage. Oecologia, 73(4), 490-500.

Quirós C., Vinyoles D. (2016). Streamflow reduction induces early parental care in Salaria fluviatilis (Asso, 1801) males. Journal of Applied Ichthyology, 32(1), 198-203.

Temporary regime assessment

The triangular diagram on the right side represents the actual river regime assessed in the river sections near the gauging station at Fabara. The three coordinates represent the permanence (relative frequency) of the three aquatic phases; *flow, isolated pools* and *dry stream bed*. The regimes shown in the triangular plot are: Quasi-perennial (Qp), Fluent-Stagnant (FS), Alternate-Fluent (AF), Stagnant (St), Alternate-Stagnant (AS), Alternate (Al), Occasional (Oc), Episodic (Ep).



Author(s): Francesc Gallart (francesc.gallart@idaea.csic.es)

35. Mühlebach (SWITZERLAND)

Kanton Thurgau, side channel of the Goldbach

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Mühlebach at Horn (Farbmühle, stat. 2309)
Coordinates (°): 47.47781, 9.45638
Catchment area (km²): 0.65
Characteristic channel width: ☒ <1 m ☐1-5 m ☐ >5 m ☐Unknown
River length (km): ~1.6
Elevation range (m a.s.l.): NA

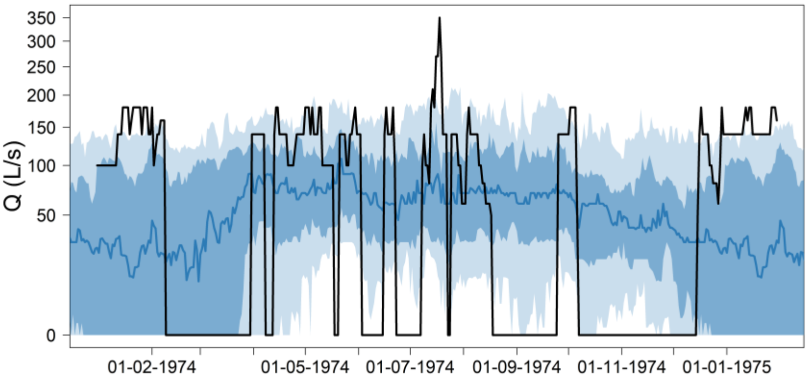
Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒ Other: Sedimentary

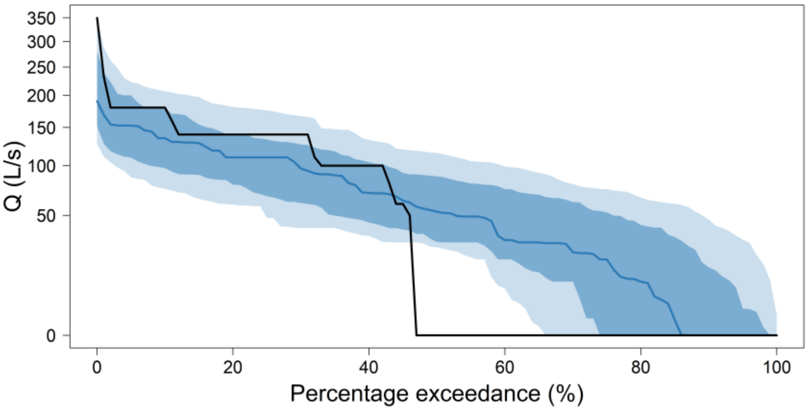
Climate:
Mean annual precipitation (mm/year): 1000
Mean annual temperature (°C): 9
Köppen class: Temperate oceanic climate (Cfb)

Land use (forest and natural, agricultural, wetlands, artificial): Agriculture and sub-urban

Artificial influence: Several mills and a power plant

Pictures of the gauging station. From: https://www.hydrodaten.admin.ch/de/2309.html





Hydrographs and flow duration curves of the Mühlebach (1976-2016) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Flow metrics (1976-2016)

MAF (m³/s): 0.07

M_{AMD} (day): 42
CV_{AMD} (day): 0.95
τ0: 28 January
$\tau 0_r$: 0.54
k: 0.87
M_{AN} (day): 66
CV_{AN} (day): 0.83

Description and reasons for intermittence

The Mühlebach is a small side channel of the Goldbach that flows into Lake Constance and the Rhine. The Mühlebach flows partly through the sub-urban areas of Tübach and Horn. Part of the stream flows underground. There are several mills and a small power plant located on the Mühlebach.

Spatial pattern: Unknown.

Seasonality: The Mühlebach has fallen dry in winter, summer and fall. The number of days with zero flow per year has varied between 0 and 153 and decreased significantly after 1994. The cause is unknown but could be related to water diversions by several power plants and mills, or due to changes at the diversion from the Goldbach at the Bruggmühle power plant. Furthermore, it has been suggested that some people block the flow in the little stream for private use, e.g. swimming.

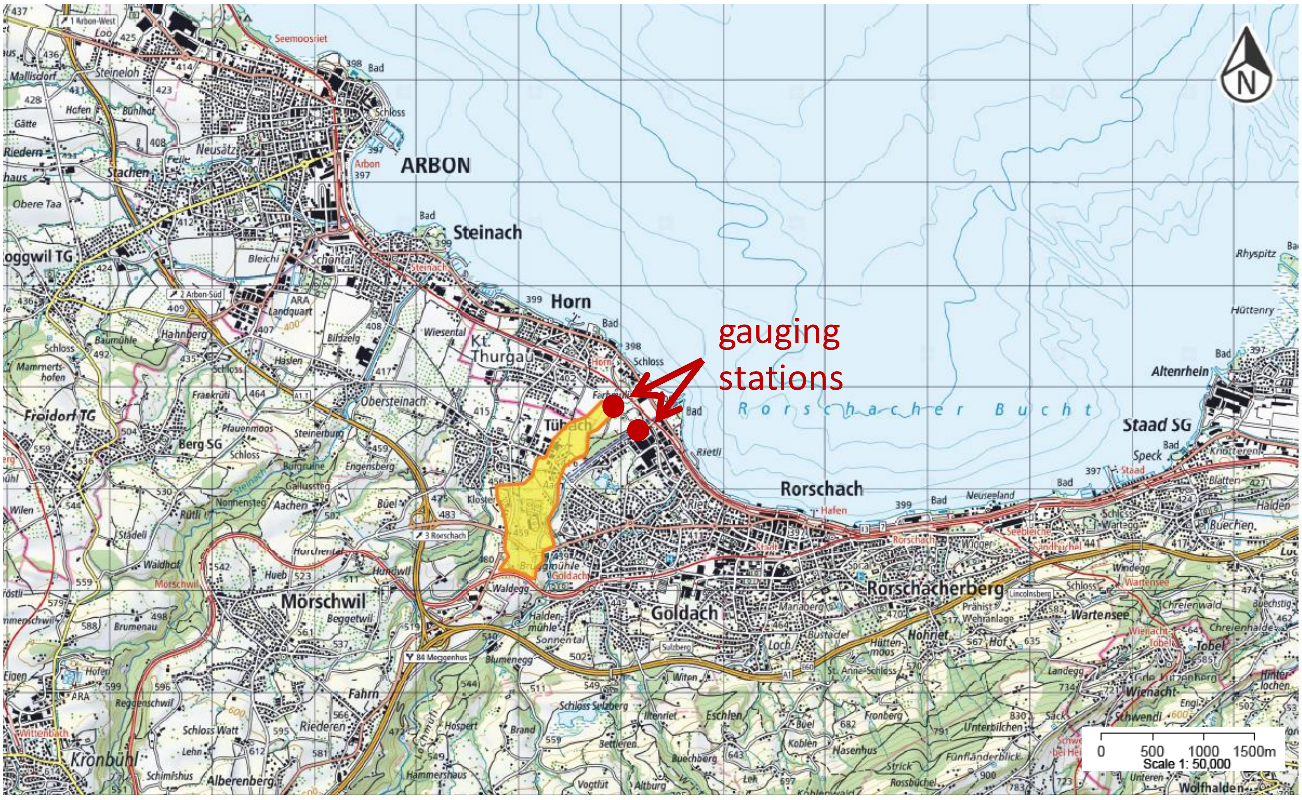
Driver(s): ☐ Summer dry period ☐Freezing/snow ☐Water management
☐Interaction with groundwater ☒ Other: based on the water level in the Goldbach

Observations of intermittence

Gauging station(s): The Mühlebach is gauged by the Swiss Federal Office of the Environment in order to obtain the total flow from the Goldbach into Lake Constance. Water flows naturally out of the Goldbach into the Mühlebach at the Bruggmühle power station. The Mühlebach gauging station is thus a supplementary gauging station (Nebenstation). The stream is very small and freezes occasionally (see picture)

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): No information on aquatic states is available for this small stream.

A fish ladder at the power plant power plant Bruggmühle was opened in November 2009 to open up old spawning grounds for lake trout in the floodplains of the Goldbachtobel. The water that flows through the fish ladder is diverted from Mühlebach.



Source: www.geo.admin.ch

Author(s): Ilja van Meerveld (ilja.vanmeerveld@geo.uzh.ch)

36. Töss (SWITZERLAND)

Kanton Zurich, tributary of the Rhine

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Töss at Atlandenberg (Awel, Stat. 519)
Coordinates (°): 47.37371, 8.86521 (WGS84)
Catchment area (km²): 66.7
Characteristic channel width: ☐ <1 m ☐1-5 m ☒ >5 m ☐Unknown
River length (km): 16
Elevation range (m a.s.l.): 621 to 1312

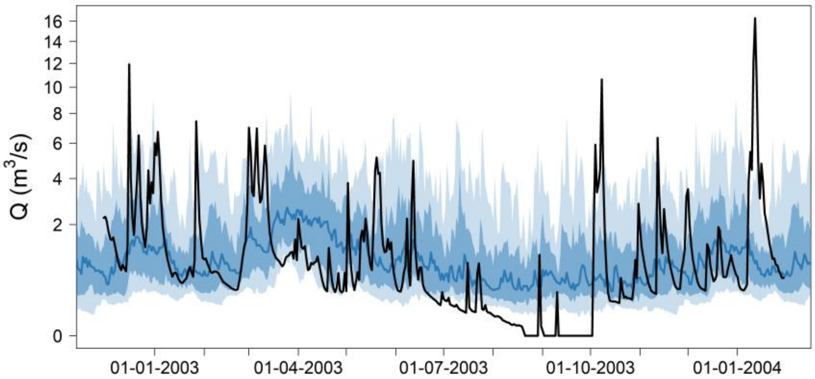
Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒Other: Sedimentary

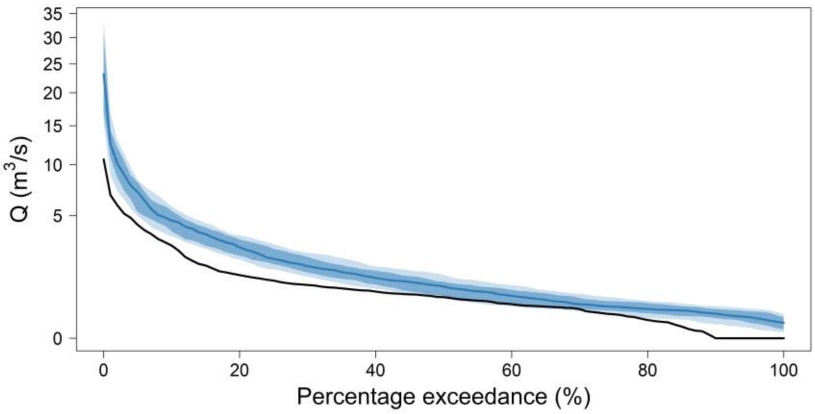
Climate:
Mean annual precipitation (mm/year): ≈ 1000
Mean annual temperature (°C): ≈ 12
Köppen class: Temperate oceanic climate (Cfb)

Land use (forest and natural, agricultural, wetlands, artificial): Forest (~70%), agriculture (~27%) and urban (<3%)

Artificial influence: Minimal

Picture of the gauging station near Bauma (ZH). From: https://www.hw.zh.ch/hochwasser/foto/0519_1.jpg





Hydrographs and flow duration curves of the Töss at Atlandenberg (1978-2015) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Fishermen saving catching fish to save them as the river dried out in 2011. https://www.tagesanzeiger.ch/zuerich/Fischer-retten-Forellen-aus-der-Toess-/story/24968625

Flow metrics (1978-2015)

MAF (m^3/s): 1.86

M_{AMD} (day): 1
CV_{AMD} (day): 4.6
$\tau 0$: 12 September
$\tau 0_r$: 0.95
k: 0.79
M_{AN} (day): 1
CV_{AN} (day): 4.7

Description and reasons for intermittence

Water from the Töss River infiltrates into the gravelly river bed, feeding the groundwater in the Töss valley. The gravel aquifer is up to 50 m deep and the annual groundwater table variations can be up to 25 m in the part of the Töss where the river falls dry regularly. Until the 19th century, the dry riverbed of the Töss was used as a road, suggesting that the river used to go dry in the past as well.

In the northernmost (downstream) section of the Töss the groundwater-level is almost at the height of the riverbed. The impermeable layer at Schlosstal (north of Winterthur, near the confluence with the Eulach) forces the groundwater to flow upwards into the riverbed, so that this lower section of the river never falls dry.

Spatial pattern: Intermittent in the middle part (and likely also in the headwaters).

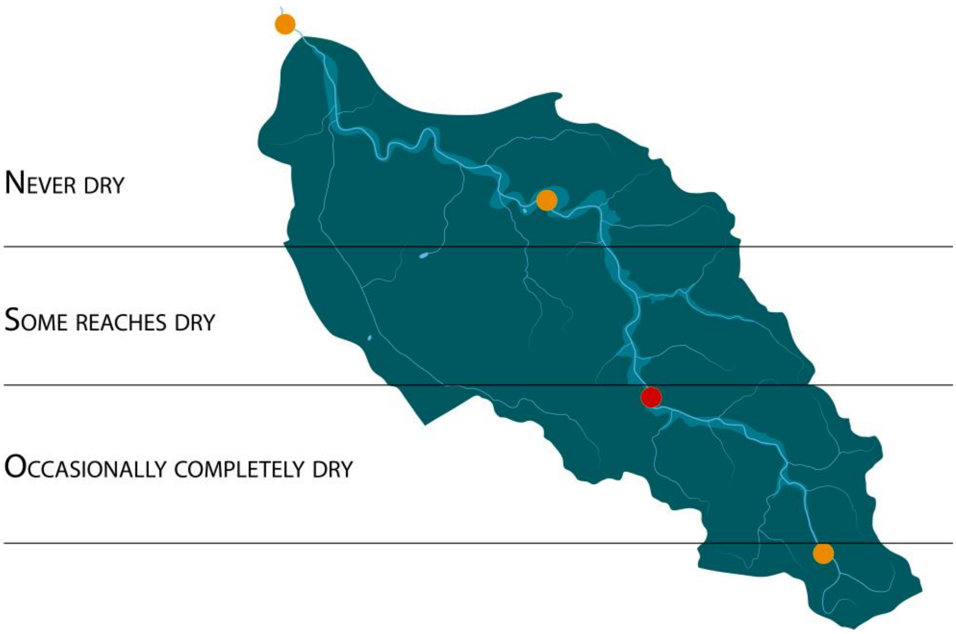
Seasonality: Flow ceases most years in summer and fall in parts of the Töss. A lack of precipitation caused parts of the Töss to go dry in March 2011 as well.

Driver(s): ☐ Summer dry period ☐Freezing/snow ☐Water management
☒Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): There are several streamflow gauging stations on the Töss river (see map below). The Atlandenberg gauging station (red dot) is located in the reach of the Töss that regularly dries out completely. Some of the reaches further downstream dry out occasionally, while further downstream and upstream the river is perennial (although likely the ungauged headwater streams are intermittent as well).

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): Although parts of the Töss go dry regularly in summer and fall, in 2011 the river went dry in March. Fish (brook trout) stranded in small pools were caught and moved several kilometres upstream. The dry sections were then 1-2 km long.



After: http://www.erdwissen.ch/tag/toess/

Author(s): Ilja van Meerveld (ilja.vanmeerveld@geo.uzh.ch)

37. Gediz (TURKEY)

Aegean Region

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Gediz at Muradiye (No. D05A025)
Coordinates (°): 38.6819, 27.3336 (WGS84)
Catchment area (km²): 15'848
Characteristic channel width: ☐ <1 m ☐1-5 m ☒ >5 m ☐Unknown
River length (km): ≈275
Elevation range (m a.s.l.): 17 to 2'308

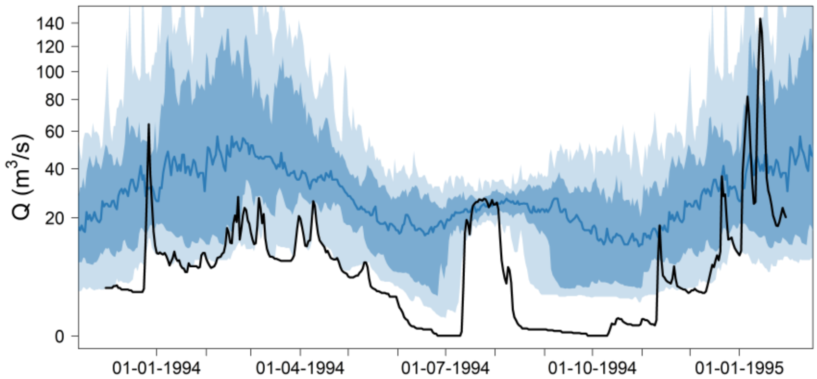
Geology: ☒ Calcareous (limestone, chalk) ☒Silicate (clay, granite)
☐Unknown ☒Other: metamorphic, flysch, schist, marble, alluvial

Climate:
Mean annual precipitation (mm/year): 617
Mean annual temperature (°C): 15.2
Köppen class: Temperate Mediterranean climate (Csa)

Land use (forest and natural, agricultural, wetlands, artificial): Agriculture (52%), forest (45%), artificial (2%) (source: CORINE Land Cover 2012)

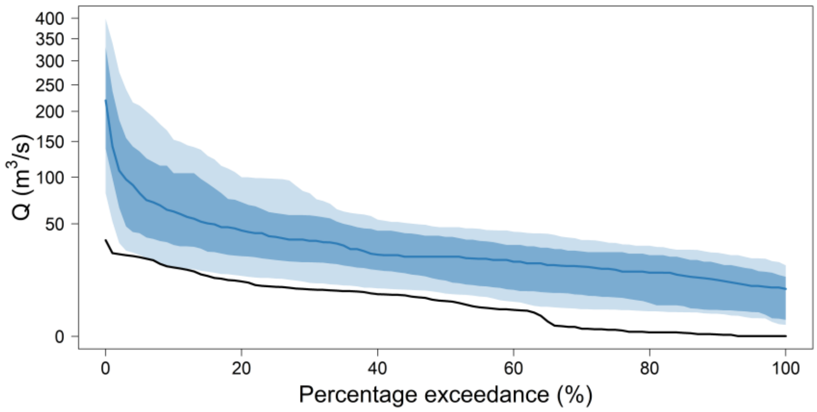
The Gediz River near the Muradiye gauging station. Photo: Alper Elçi

Artificial influence: Five reservoirs in operation for irrigation, power generation and drinking water supply; several irrigation ponds, groundwater abstraction is significant; several diversion structures channel



Flow metrics (1968-2000)

MAF (m^3/s):	38.59
M_{AMD} (day):	1
CV_{AMD} (day):	3.90
$\tau 0$:	21 June
$\tau 0_r$:	0.85
k:	0.89
M_{AN} (day):	1
CV_{AN} (day):	4.19



Hydrographs and flow duration curves of the Gediz at Muradiye (1968-2000) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Description and reasons for intermittence

The Gediz River basin is located in the Aeagean region of western Turkey. It has a drainage area of 17’176 km^2. The main springs of the river are located in Mount Murat located in the northeast of the basin and Mount Bozdağ at an elevation of about 2’000 m. Snow pack occurrence and snow melt processes can only be observed in the upstream parts. Main reason for the ephemeral character of the river is the semi-arid climate with dry summer months. The secondary reason for intermittence is the abstraction and diversion of flow for different purposes. Due to extensive groundwater pumping for irrigation during the growing season, the main reach of the Gediz River is affected by losing water to the underlying aquifer through infiltration. Furthermore, the Gördes and Demirköprü reservoirs, and the water diversion structures along the main reach can affect discharge of the river significantly although not on a regular basis.

Spatial pattern: Flow is almost perennial in the upper reaches of the river, upstream of the Demirkopru reservoir (38.693 N, 28.415 E). Downstream of the reservoir, intermittent flow stretches are sporadic. Water diversion structures around Golmarmara, in the vicinity of the middle reaches of the river, more intermittence of flow can be observed. Water is usually present downstream although flow may not occur in summer months and disconnected pools can be observed here.

Seasonality: Flow ceases mainly in summer months and inter-annual variability depends on whether annual precipitation is above or below historical averages. Depending on the location, discharge can be non-existent from middle of July to end of September. However, the temporal pattern is inconsistent on an interannual basis. Duration of intermittence is also variable and depends on the location.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☒Water management
☒Interaction with groundwater ☒ Other: water diversion for irrigation

Observations of intermittence

Gauging station(s): The Muradiye gauging station is located 20 km upstream of the basin outlet and has a long historical record of observations (1968-2000) with 96.8% completeness. Flow observation after year 2000 exist, however daily records were not publicly available when this report was written. Monthly records are available. The mean values of the 10^{th} percentile of maximum and minimum discharges at this station are 103.57 and 0.944 m^3s^{-1}, respectively. Maximum discharge occurs in February and minimum discharge in October. Flow intermittence at this station was observed for prolonged periods in 1994 and 1995. Other gauging stations in the basin display similar discharge characteristics. Intermittence is observed at almost all stations on the main reach of the river. Intermittence is particularly pronounced on tributaries.

Flow/aquatic state observations (e.g. “flow”, “disconnected pools”, “dry bed”): Flow/aquatic state observations are not recorded in this basin; however, if there is no flow discharge at the gauging stations the measurement is recorded as “dried out”.

Author(s): Alper Elçi (alper.elci@deu.edu.tr)

38. Küçük Menderes (TURKEY)

Aegean Region

Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Küçük Menderes at Selcuk (No. E06A001)
Coordinates (°): 37.9791, 27.3794 (WGS84)
Catchment area (km²): 3’255.2
Characteristic channel width: ☐ <1 m ☐1-5 m ☒ >5 m ☐Unknown
River length (km): ≈130
Elevation range (m a.s.l.): 4 to 2157

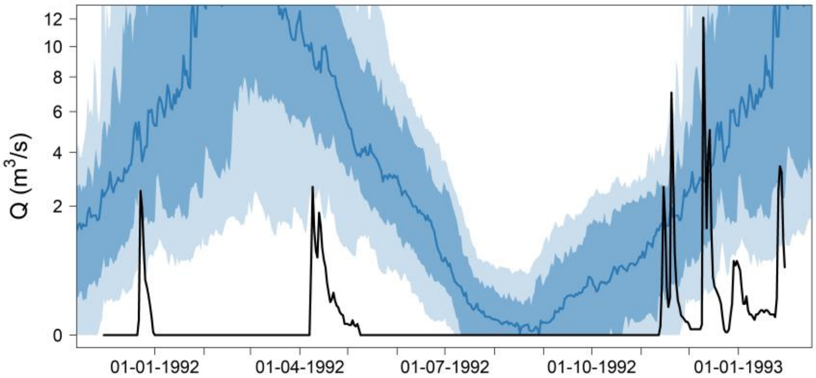
Geology: ☐ Calcareous (limestone, chalk) ☐Silicate (clay, granite)
☐Unknown ☒Other: metamorphic, marble, alluvial

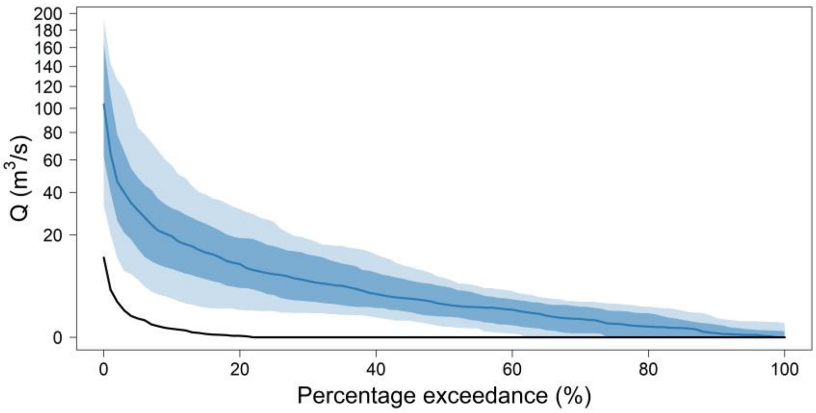
Climate:
Mean annual precipitation (mm/year): 661
Mean annual temperature (°C): 17
Köppen class: Temperate Mediterranean climate (Csa)

Land use (forest and natural, agricultural, wetlands, artificial): agriculture (57%), forest (40%), artificial (2%) (source: Corine Land Cover 2006)

Artificial influence: Three reservoirs in operation for irrigation and drinking water supply; several irrigation ponds, groundwater abstraction is significant; diversion structure for irrigation channel

Near the gauging station, downstream reach of the river observed in February 2019 when flowrate is at annual maximum





Hydrographs and flow duration curves of the Küçük Menderes at Selçuk (1952-2012) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Flow metrics (1952-2012)

MAF (m^3/s):	9.05
M_{AMD} (day):	49
CV_{AMD} (day):	1.20
$\tau0$:	21 July
$\tau0_r$:	0.85
k:	0.85
M_{AN} (day):	53
CV_{AN} (day):	1.25

Description and reasons for intermittence

The Küçük Menderes River basin is located in the Aeagean region of western Turkey. It has a drainage area of 3'491 km^2. The main springs of the river are located in Mount Beydag at an elevation of approximately 2'000 m. Snow pack occurrence and snowmelt processes can only be observed in the upstream region. Main reason for the ephemeral character of the river is the semi-arid climate with dry summer months. The secondary reason for intermittence is the fluctuation of groundwater levels. Groundwater is a significant resource in the basin and the water table level strongly influences flow interaction with the river. Due to extensive groundwater pumping for irrigation during the growing season, the Küçük Menderes River loses water in almost all reaches through infiltration to the aquifer. The Beydag reservoir on the main reach and a water diversion structure further downstream can affect discharge of the river.

Spatial pattern: Flow is almost perennial in the upper reaches of the river, upstream of the Beydag reservoir (38.125 N, 28.223 E). Downstream of the reservoir, intermittent flow stretches are sporadic. Due to groundwater interaction flow in the middle reaches of the river are more intermittent than in the downstream reaches. Wastewater discharges to the tributaries and main reach can constitute a significant fraction of total flow. Therefore, water is usually present downstream although flow may not occur in summer months and disconnected pools can be observed here.

Seasonality: Flow ceases mainly in summer months almost every year. Depending on the location, discharge can be non-existent from middle of July to end of October. However, the temporal pattern is inconsistent on an interannual basis. Furthermore, in the dry months of the year, flow may constitute only of wastewater discharged into the river.

Driver(s): ☒ Summer dry period ☐Freezing/snow ☒Water management
☒Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): There are 10 gauging station in the Küçük Menderes River basin. Two of them are closed as of 4.4.2019. The Selcuk gauging station is located 11 km upstream of the basin outlet and has a long historical record of observations (1952-2012) with 97% completeness. This station is currently closed. The mean values of maximum and minimum discharge at this station are 28.86 and 0.17 m^3s^{-1}, respectively. Maximum discharge occurs in February and minimum discharge in August. Other gauging stations in the basin display similar discharge characteristics. Intermittence is observed at all stations. Intermittence is in particular pronounced on tributaries. The lowest values for mean minimum discharge is 0.01 m^3s^{-1} for the tributaries and 0.17 $m^3s^{-1}$for the main reach of the river. The length of intermittence can be as long as two months during drought periods

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): Flow/aquatic state observations are not recorded in this basin; however, if there is no flow discharge at the gauging stations the measurement is recorded as "dried out".

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39. East Glen (UNITED KINGDOM)

Welland catchment, Anglian Region

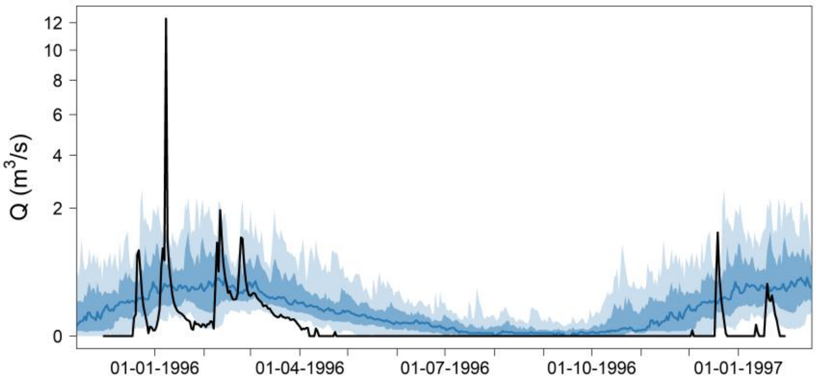
Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: East Glen at Manthorpe (UK NRFA 31008)
Coordinates (°): 52.7309, -0.4200 (WGS84)
Catchment area (km²): 136.2
Characteristic channel width: ☐ <1 m ☒1-5 m ☐ >5 m ☐Unknown
River length (km): 37 km (to East-West Glen confluence)
Elevation range (m a.s.l.): 16.9 to 131.6

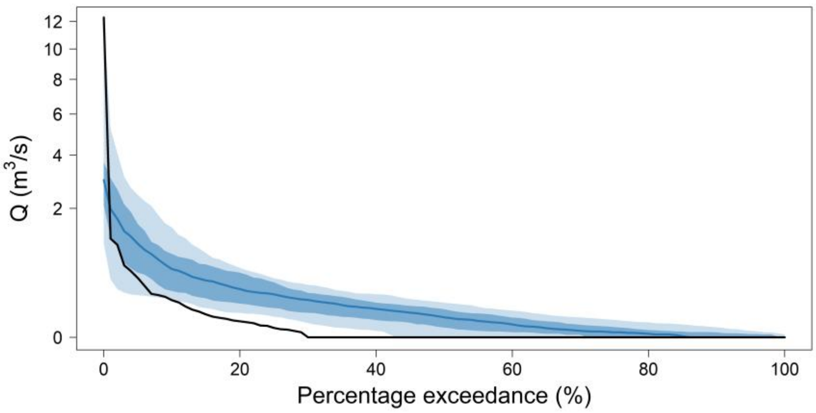
Geology: ☒ Calcareous (limestone, chalk) ☐Silicate (clay, granite) ☐Unknown ☒Other:

Climate:
Mean annual precipitation (mm/year): ≈ 610
Mean annual temperature (°C): ≈ 10
Köppen class: Temperate oceanic (Cfb)

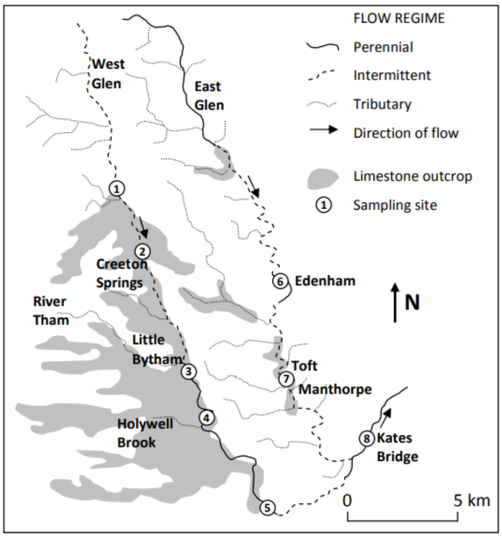
Land use (forest and natural, agricultural, wetlands, artificial): Arable (66%), grassland (17%), woodland (14%), urban (3%)

Artificial influence: The Lincolnshire Limestone is a major aquifer in eastern England, and has been extensively developed for public water supply. Groundwater levels in the catchment have been declining since 1940 (Petts, 1990), and the river is considered to be over-abstracted (Environment Agency, 2013)





Hydrographs and flow duration curves of the East Glen at Manthorpe (UK NRFA 31008) (1968-2017) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale



Location map of the River Glen, indicating sampling points (Stubbington, 2011)

Manthorpe Gauging Station. Photo: Mat Fascione, Creative Commons Licence

Flow metrics (1968-2017)

MAF (m³/s):	0.27
M_{AMD} (day):	63
CV_{AMD} (day):	1.12
$\tau 0$:	2 July
$\tau 0_r$:	0.70
k:	0.77
M_{AN} (day):	93
CV_{AN} (day):	0.83

Description and reasons for intermittence

The River East Glen flows over Jurassic Lincolnshire Limestone. Its intermittence thus has both natural and artificial drivers, with the hydrogeological behaviour of the karst bedrock and localised drift deposits compounded by the development of the aquifer for water resources (Environment Agency Catchment Data Explorer, accessed 20/01/2019).

Spatial pattern: In the upper and middle reaches of the East Glen, streamflow originates from both surface runoff from impermeable strata and from groundwater spring inputs from minor aquifers. Further downstream, between Toft and Manthorpe, localised outcropping results in the loss of a significant proportion of streamflow to the limestone aquifer, resulting in intermittent flow in these reaches (Stubbington, 2011, and references therein).

Seasonality: The East Glen experiences streambed drying during the summer months in most years (Stubbington, 2011).

Driver(s): ☐ Summer dry period ☐Freezing/snow ☒Water management
☒Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): The UK National River Flow Archive (NRFA, available at https://nrfa.ceh.ac.uk/, accessed on 06/09/2018) holds daily mean flows, hydrometric and spatial information for two gauging stations on the East Glen: Manthorpe (NRFA station 31008), and further upstream at Irnham (NRFA station 31013). The loss of water to the aquifer between the two gauging stations means that low flows are greater and intermittence rarer at Irnham. Periods of flow cessation (flow ≤ 0.001 m^3s^{-1}) of at least one month in duration have been recorded at Manthorpe gauging station in 22 of the 50 years since the record began in 1968. Typically these periods occur between April and September. The longest period of flow cessation unaffected by missing data was 336 days, from May 2011 until April 2012.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): Observations during a wet year show that discharge at Toft (approx. 1 km upstream of Manthorpe) receded until complete drying of a short stretch occurred possibly for 1-2 weeks, whereas Edenham (approx. 5 km upstream of Manthorpe) became ponded or retained very slow flow, the width of the channel remaining stable at lowest discharge in some parts of the site.

Ecological value

The East Glen is among the rivers dissecting the Kesteven Uplands *Landscape Character Area*, and it has been characterized as providing ecosystem services including water provision, regulation of water quality, and cultural value (Natural England, 2014). As in other rivers, temporal variability in discharge among years can promote invertebrate diversity (Bickerton, 1995) and the subsurface sediments may provide a refuge for aquatic invertebrates during dry phases (Stubbington *et al.*, 2011).

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Petts G.E. (1990). An environmental assessment of the proposed water resource development of the River Glen, Lincolnshire. 2 volumes. National Rivers Authority, Anglian Region.

Stubbington *et al.* (2011). Spatial variability in the hyporheic zone refugium of temporary streams. Aquatic Sciences, 73(4), 499-511.

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40. Mimram (UNITED KINGDOM)

Lee catchment, Thames Region

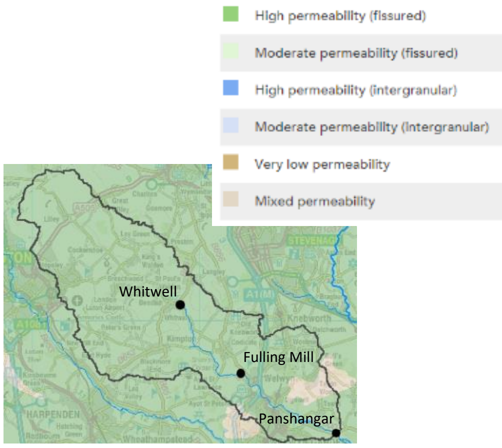
Characteristics from the catchment at: ☐ the outlet
☒ the gauging station: Mimram at Fulling Mill (UK NRFA 38011)
Coordinates (°): 51.8377, -0.2213 (WGS84)
Catchment area (km²): 98.7
Characteristic channel width: ☐ <1 m ☒1-5 m ☐ >5 m ☐Unknown
River length (km): 22.3
Elevation range (m a.s.l.): 65.7 to 193.0

Geology: ☒ Calcareous (limestone, chalk) ☐ Silicate (clay, granite)
☐Unknown ☐ Other:

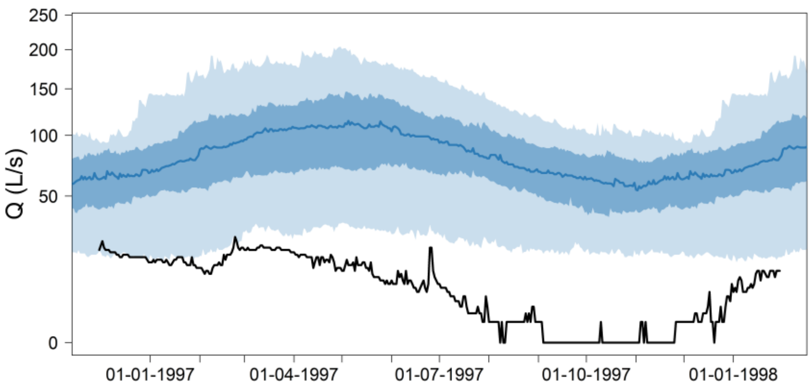
Climate:
Mean annual precipitation (mm/year): 658
Mean annual temperature (°C): 9.5
Köppen class: Temperate oceanic (Cfb)

Land use (forest and natural, agricultural, wetlands, artificial): arable (64%), grassland (18%), woodland (11%), urban (7%)

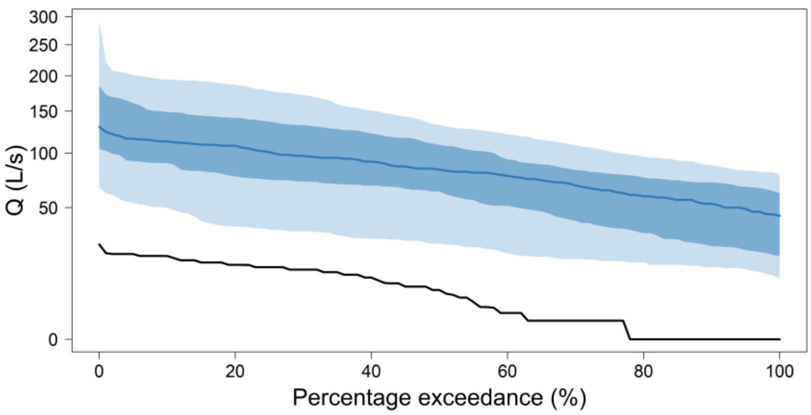
Artificial influence: Significant losses to groundwater abstraction



Catchment geology for the Mimram at Panshangar, showing Whitwell, Fulling Mill and Panshangar gauging stations



River Mimram, with Fulling Mill gauging station seen in the distance.
Environment Agency, 3 March 2012



Hydrographs and flow duration curves of the Mimram at Fulling Mill (UK NRFA 38011) (1970-2016) (year with the highest proportion of zero flows in black; interdecile and interquartile ranges in blue shaded areas; median in dark blue). The y-axis displays a square-root scale

Flow metrics (1970-2016)

MAF (m³/s): 0.09

M_{AMD} (day): 2
CV_{AMD} (day): 6.65
$\tau 0$: 27 August
$\tau 0_r$: 0.93
k: 0.98
M_{AN} (day): 3
CV_{AN} (day): 6.71

Description and reasons for intermittence

The intermittence of the Mimram has both natural and artificial drivers as flows are dominated by baseflow from the slowly responding Chalk aquifer that have been substantially diminished by groundwater abstraction.

Spatial pattern: The upper reaches of the Mimram display typical chalk stream behaviour, with the source migrating downstream as groundwater levels recede and upstream as they recover. In an average year, this network contraction takes place during the summer months, and expansion during the winter months. However, when a dry winter suspends recharge, contraction may continue into a second year, and flow may also cease in the mid-reaches. Since Fulling Mill GS is located in these mid-reaches, the mean annual number of days with no flow is greater than at Whitwell GS upstream.

Seasonnality: Cessations of flow were recorded at Fulling Mill from August to November 1976, June to October 1992, June 1997 to March 1998, July to December 2006 and in April 2012. Periods with no flow typically begin in the summer months as groundwater levels and baseflows recede and are of several months' duration.

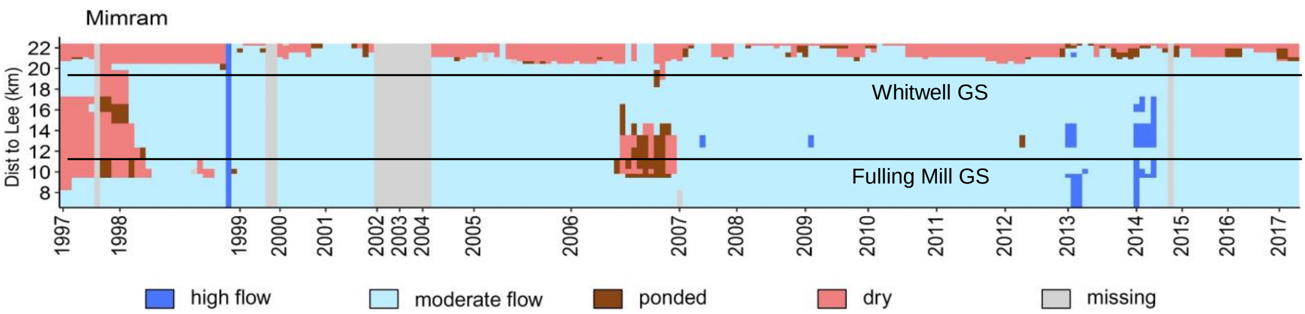
Driver(s): ☐ Summer dry period ☐ Freezing/snow ☒ Water management
☒Interaction with groundwater ☐ Other:

Observations of intermittence

Gauging station(s): The UK National River Flow Archive (available at https://nrfa.ceh.ac.uk/, accessed on 29/12/2018) holds daily mean flows for three gauging stations on the Mimram: Whitwell (38017) in the upper reaches, Fulling Mill (38011) in the middle and Panshanger Park (38003) in the lower reaches. Intermittency is observed at Whitwell and Fulling Mill, whilst observed flows at Panshangar Park are perennial. The quality and consistency of daily mean flows at Fulling Mill, which began in 1955, is poorer than that of the other gauging stations but accurate in the modular range of the Crump weir and well located for capturing intermittence.

Flow/aquatic state observations (e.g. "flow", "disconnected pools", "dry bed"): Surveys of aquatic state began in 1997 with approximately monthly frequency, from 7.3 to 22.3 km from the confluence with the River Lee. Monitoring frequency was increased during times of hydrological extreme, and reduced (or suspended in 2002-2004), in response to resource constraints. The heat map of observations (below) with a fourfold classification of hydrological state reveals both spatial and temporal patterns in aquatic state spanning 20 years.

Visualisation of hydrological state with good temporal and spatial resolution (Sefton et al., 2017)



Sefton *et al*. (2017). Visualising and quantifying flow intermittence patterns in chalk streams. The Springs and Sources dataset of Hertfordshire and North London Area of the Environment Agency. Report for Environment Agency, pp. 66. Centre for Ecology & Hydrology, UK.

Balancing environmental and human demand for water

Building on numerous studies of chalk stream hydrology and ecology, the region has been used in developing an approach for their ecological assessment (Westwood *et al.*, 2017) and the Mimram itself to assess the benefits of alleviating low flows (Hanley *et al.*, 2003). In 2018, the Environment Agency secured a significant reduction in groundwater abstraction for water supply from the Mimram catchment, alongside morphological improvements to maximise the benefit of the reduction to the environment.

Westwood *et al*. (2017). An approach to setting ecological flow thresholds for southern English chalk streams. Water Environ J., 31(4) 528-536.

Hanley *et al.* (2003). Aggregating the benefits of environmental improvements: distance-decay functions for use and non-use values. J Environ Manage, 68(3) 297-304.

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