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Methodological approach for the assessment of the conservation status of European grayling

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Executive Summary

This report presents the current state methodology developed within the EU research project ProtectFish (Horizon Europe) on the assessment of the conservation status of European grayling (*Thymallus thymallus*). Such a method is needed, since several listed species, like European grayling, lack target reference values. As a result, the classification of conservation status often relies on expert knowledge rather than objective, data-based criteria. We propose a new approach, aiming to standardise the assessment of conservation status for European grayling.

The central approach is based on calculating the theoretical minimum viable population size (MVP), representing the smallest population size that ensures a 99 % probability of survival for 100 years under optimal conditions constructing a simple population model. Taking into account realistic regional environmental stressors (e.g., temperature), the required population size (RPS) is derived by the same model. Subsequently, the RPS is projected into the available habitat, allowing calculation of the target fish stock (TFS) for specific streams or sub-catchments. This fish stock can then be compared to fish stock data for the specific stream. Assuming that the target fish stock represents the lower threshold of fish density representing the favourable conservation status.

Key findings are:

- The used model allows the estimation of MVP and RPS.
- Threshold values for required population sizes for 720 stressor combinations have been defined for Europe, which are ready to be applied for conservation status assessment, requiring only minor adjustments depending on geographic region and data availability.
- With the available observational fish stock data, an assessment of the conservation status is generally feasible; however, the quality of the data (e.g. sampling methods and spatial resolution) strongly influences the interpretability and reliability of the results. Data quality should therefore always be considered when interpreting the findings.

Ultimately, this method should enable regional authorities, responsible for the conservation status assessments – such as local nature conservation authorities or state environmental agencies – to quantitatively assess the conservation status as the ratio of existing to target fish density. It must be emphasized that we deliberately refrain from providing a strict reference or evaluation framework, as the official assessment of conservation status under the Habitats Directive is the exclusive responsibility of the competent authorities. The described method represents an improvement in defining favourable conservation status for the European grayling and moreover, is intended to



contribute to the prioritization of habitat improvement measures. **The methodology described in detail here is an interim product of Work Package 3 (WP3: Calculation of MVP and Conservation Status).** It represents an initial practice-oriented methodological proposal intended to serve responsible authorities as a supporting tool. Applicability and practicability are the primary focus; based on the experience gained, the approach will be further optimized and refined in future.



1. Introduction

1.1. Background and objectives

European Union Member States have both the legal mandate and the obligation to protect species and their habitats. On the one hand, achieving a good ecological status of water bodies is essential for fulfilling the objectives of the European Water Framework Directive (WFD, Directive 2000/60/EC). On the other hand, the Habitats Directive (Directive 92/43/EEC) obliges Member States to maintain natural habitats and wild fauna and flora, in particular to ensure the favourable conservation status of the species and habitat types listed in the Annexes of the Directive.

European member states are responsible for reporting under Article 17 of the Habitats Directive. Reports include information on the conservation status of listed species. The conservation status of a species is evaluated according to the factors: population, habitat, range and future prospects. A favourable conservation status is reached when

- “population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and
- the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and
- there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.” (Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, 1992).

Significant constraints in this reporting are the lack of methodological harmonisation in methods, units and sampling designs, inadequate monitoring programmes, and a high proportion of assessment, where the status is “unknown” (Lorilla et al., 2025). Even where data are available through regional or national monitoring programmes, the interpretation of the data remains challenging. In practice, within water management authorities, the evaluation of fish communities is currently based mainly on expert knowledge interpreting taxonomic composition, species abundance, and age structure. In many cases, no reference values such as target fish stocks exist for the FFH-listed species so there is a lack of objective criteria. Furthermore, the prediction of the long-term viability of a population – and thus a quantitative assessment of the population and future prospects criteria – is missing (Mehtälä & Vuorisalo, 2007).



1.2. Current conservation status reporting of the grayling (Annex V)

Since the 1980s, grayling populations have declined sharply in large parts of Europe (Mruk et al., 2024; Persat, 1996; vom Berge et al., 2025). This decline is driven by various stressors, including the loss of suitable habitats, disrupted connectivity, rising water temperatures due to climate change, and predation pressure (Jepsen et al., 2018; Marsh et al., 2021; Mruk et al., 2024; Rosenau et al., 2025). The European grayling (*Thymallus thymallus*) inhabits cold, clear and well-oxygenated stream sections. It serves as an indicator of ecologically intact freshwater systems.

The species is currently listed as “Least Concern” on the IUCN red list. For the reporting under Article 17, European member states gather information on the listed species from the authorities and report the conservation status of listed species to the EU for the biogeographic regions (Figure 1). The European Environment Agency published the Habitats Directive reporting from 2019-2024 on progress and implementation of Article 17: Across the reporting countries, the European grayling (species code 1109) is in an unfavourable conservation status in the vast majority of biogeographic regions. Only Sweden records a favourable conservation status in boreal and alpine regions (FV), while all other countries assessed their populations as either unfavourable-inadequate (U1) or, more commonly unfavourable-bad (U2). The dominant trend is the decline of observed population densities, with only Sweden reporting improvements in some regions. Consequently, population consistently emerges as the most critically assessed parameter, frequently rated worse than range or habitat quality. The official assessment reports (Table 1, Austria, 2026; Belgium, 2026; Czechia, 2026; Denmark, 2026; Finland, 2026; France, 2026; Germany, 2026; Lithuania, 2026; Poland, 2026; Romania, 2026; Slovakia, 2026; Sweden, 2026) also highlight persistent knowledge gaps – several states, were unable to assess several parameters due to insufficient data (Table 1: marked as ‘XX’), underscoring the broader challenge of data availability in conservation status reporting.



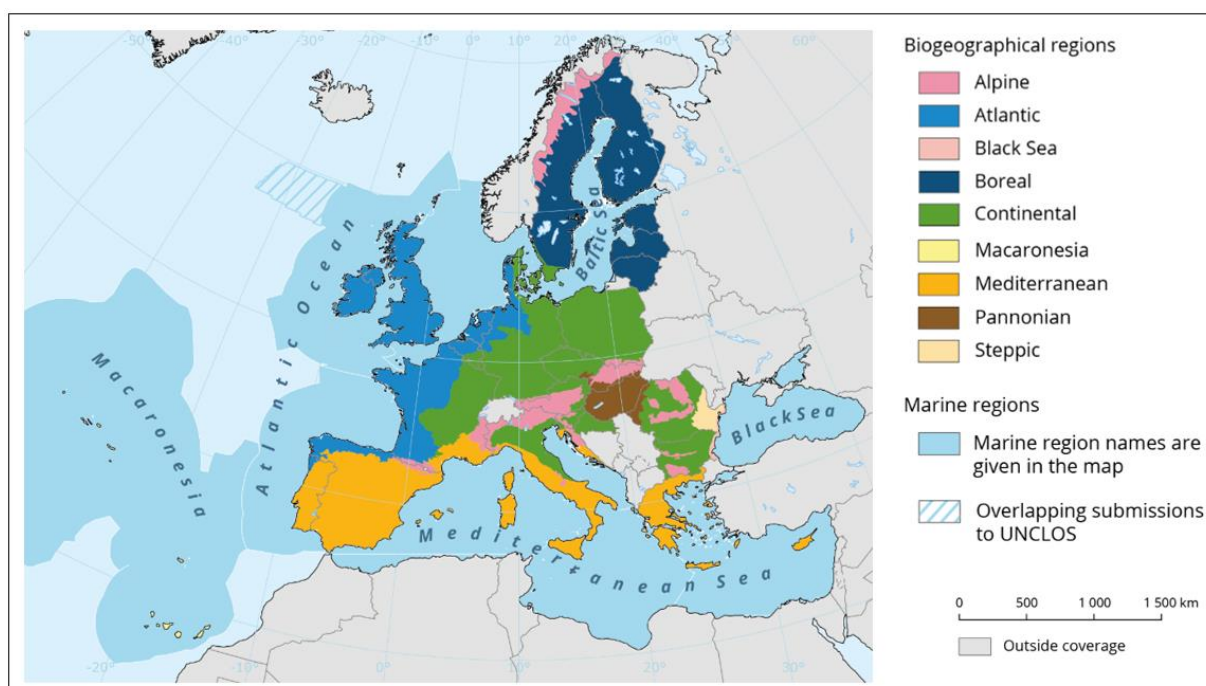


Figure 1: Biogeographical and marine regions in the EU, defined by the EEA. Reference data: ESRI (EEA 2020).

Table 1: Conservation status assessments reported by the European member states of European grayling (*Thymallus thymallus*) under Article 17 of the Habitats Directive for European countries within the species' core distribution range for the reporting cycle 2019-2024 (Austria, 2026; Belgium, 2026; Czechia, 2026; Denmark, 2026; Finland, 2026; France, 2026; Germany, 2026; Lithuania, 2026; Poland, 2026; Romania, 2026; Slovakia, 2026; Sweden, 2026). The conclusions for the species are listed here. Habitats Directive reporting (Art. 17) - 2019-2024, Report on progress and implementation of Article 17, Habitats Directive (EU). The abbreviations describe the conservation status: Favourable (FV), Unfavourable – Inadequate (U1), Unfavourable – Bad (U2), Unknown (XX) and the trend: Stable (S), Increasing (I), Decreasing (D), Unknown (Unk) in the biogeographical regions Alpine (ALP), Atlantic (ATL), Boreal (BOR), Continental (CON), Marine Baltic (MBAL), Mediterranean (MED), Pannonian (PAN) (European Environment Agency [EEA], 2026).

Country	Re- gion code	Range	Popula- tion	Species habitat	Future pro- spects	Overall assess- ment	Overall trend
Austria	ALP	FV	U1	U1	U1	U1	D
Austria	CON	U2	U2	U1	U2	U2	D
Belgium	CON	FV	U2	FV	U1	U2	D
Belgium	ATL	XX	U2	U2	U1	U2	Unk
Czechia	PAN	U2	U2	U2	U2	U2	S
Czechia	CON	U2	U2	U1	U2	U2	S
Denmark	ATL	U2	U2	XX	U2	U2	S
Denmark	CON	U2	XX	XX	XX	U2	Unk



Finland	FV	FV	FV	FV	FV	S	FV
Finland	FV	XX	XX	XX	XX	Unk	FV
Finland	U2	XX	U2	U2	U2	D	U2
France	ALP	U2	U2	U2	U2	U2	D
France	CON	U1	U1	U1	U2	U2	D
France	MED	U1	U1	U1	U1	U1	D
Germany	CON	U1	U1	U1	U1	U1	D
Germany	ATL	U2	U2	U2	U2	U2	D
Lithuania	BOR	FV	FV	FV	FV	FV	S
Poland	ALP	FV	U2	FV	U2	U2	D
Poland	CON	FV	U2	FV	U2	U2	D
Romania	ALP	U2	XX	U2	U2	U2	D
Romania	CON	U2	XX	U2	U2	U2	D
Slovakia	ALP	U1	U1	U1	U1	U1	D
Slovenia	ALP	U1	U1	U1	U1	U1	D
Slovenia	CON	U1	U1	U1	U1	U1	D
Sweden	MBAL	U2	U1	XX	U2	U2	I
Sweden	BOR	FV	FV	FV	FV	FV	D
Sweden	ALP	FV	FV	FV	FV	FV	I

1.3. Rationale

European grayling populations have declined to critically low densities across much of their range, raising serious concerns about their long-term viability. This poses two interconnected challenges. First, for conservation status assessments under Article 17, a quantitative threshold is needed to determine at what point a population density becomes critically low – information that is currently lacking for most member states. Second, from a management perspective, the absence of defined target stock sizes makes it difficult to set meaningful recovery goals or evaluate the effectiveness of conservation measures. A robust estimation of the target fish stock, based on population dynamics, is lacking. We developed a simple population model to address both needs, providing a data-driven benchmark that can inform the assessment of conservation status and the development of targeted management strategies for grayling-inhabited streams.

Populations require a critical minimum size to persist in the long term (minimum viable population, MVP). This size is influenced by a multitude of biological and ecological



processes. Both genetic and demographic effects define this population threshold (Wang et al., 2019).

A critical minimum population size is needed to sustain a population despite random events and to ensure robustness against genetic effects such as genetic drift and inbreeding depression. A certain population size is required for it to remain viable despite demographic effects (random fluctuations in sex ratios or survival rates) and environmental stochasticity (e.g., extreme weather events or local disease outbreaks). Furthermore, in small populations, the probability that closely related individuals will mate increases. This leads to the fixation of deleterious recessive alleles, reduces genetic variability, and consequently diminishes the population's capacity to adapt to environmental changes or emerging pathogens. Relative to other animal groups European grayling has a comparatively high reproductive potential with 3,000–8,000 eggs per adult female (Hertig, 2006; Kodela et al., 2023), but also experience naturally high mortality during early life stages. As a result, the species can theoretically respond rapidly to favourable conditions. However, juvenile stages are extremely vulnerable and are therefore particularly susceptible to short-term adverse influences, such as sudden heat stress events or eutrophication (Bašić et al., 2018; Hübner et al., 2009). The goal of MVP analysis is to determine the smallest population size that ensures a 99 % probability of long-term survival, usually for a specified number of generations or 100 years (Wang et al., 2019).

To determine the target size for individual European grayling populations, we developed a method which calculates the target fish stock (TFS) for a specific stream in three sequential steps (Figure 2). The theoretical population model assumes that populations under multiple stressors must be larger to remain stable due to higher mortality rates at stressful conditions, than populations in pristine conditions. In a first step, MVP is calculated under optimal habitat conditions. In a second step, the fecundity rates and survival rates are recalculated for site specific stressor combinations. We identified flow regime, water temperature, streambed clogging, hydromorphological quality, cormorant predation and fishing pressure (angling) as potential main stressors. For each main stressor, different sub-conditions can be assigned: for example, the flow stressor enables the calculation of the required population size (number of fish) for streams with low discharge, damming and hydropeaking. The combination of all possible sub-conditions across all stressors yields a total of 720 scenarios, for which required population sizes were modelled. The resulting number of individuals is defined as the required population size (RPS). In a third step, the translation of RPS to a value of use for the assessment of the conservation status is achieved through calculation of a target fish stock (TFS) by the quantification of available habitat for the estimated required population size in a specific catchment or sub-catchment. Target metrics for the TFS include individuals per



unit area (ind m^{-2} ; ind ha^{-1}) and individuals per unit river length (ind m^{-1} ; ind km^{-1}). Ultimately, the target fish density and observed fish density can be compared to assess conservation status.

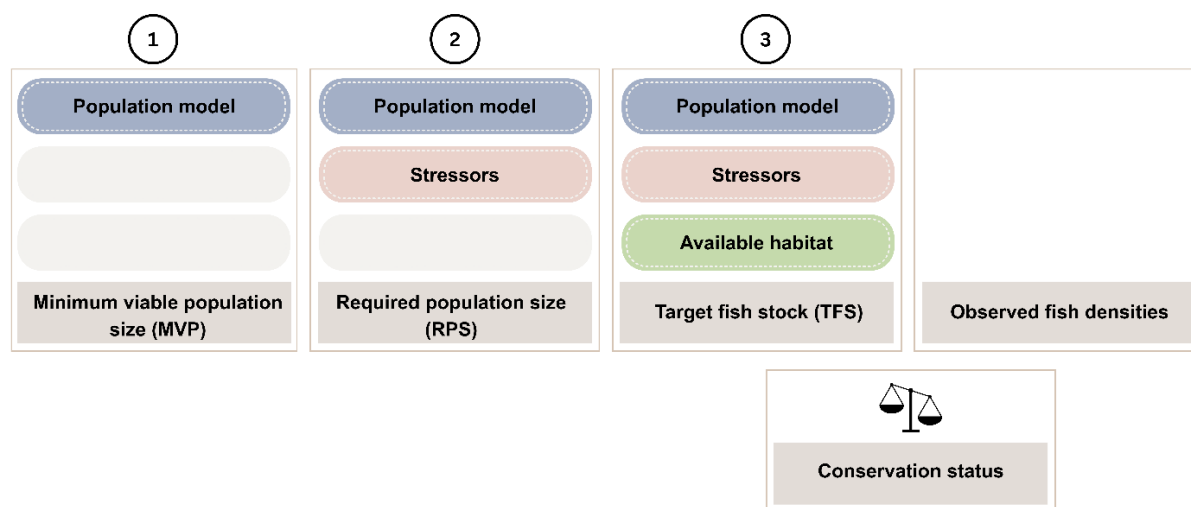


Figure 2: Method for determining the conservation status in three steps. First, the minimum viable population size (MVP) is calculated with a literature-based population model. Second, the required population (RPS) size is calculated for 720 stressor combinations which reduce fecundity and survival rates. In the third step, the RPS is projected in the available habitat which results in the target fish stock (TFS). By comparing TFS and observed fish densities, the assessment of the conservation status can be improved.

2. Population model, parametrisation and estimation of minimum viable population size (MVP)

The theoretical MVP is estimated using a literature-based population model. The model is parameterised using a mean expected lifespan of individuals (8+, Hertig 2006, Droll et al. 2025), the age at which individuals reach sexual maturity (3+ and / or total length > 25 cm at spawning in March, Droll et al., 2025; Hertig, 2006), and the average fecundity of females as a function of body size (based on mean growth of European grayling in Central Europe, Droll et al., 2025; Hertig, 2006; Näslund et al., 2005; Paquet, 2002). In addition, survival rates are defined across eight age classes (supplements S 1 - S 2). The model therefore represents the following life cycle: Grayling eggs are deposited in spring by adult females in spawning habitats (egg number), subsequently fertilised by males (fertilisation rate), develop through the eyed-egg stage (egg survival), pass through the yolk-sac stage (yolk sack abs survival), emerge and begin active swimming (survival swim up), and then enter the larval stage (survival fry). By late



summer, individuals reach a body length of approximately 8–12 cm and thus enter the juvenile stage. The juvenile stage defines the starting point of the simulation. Reductions in fecundity or survival at earlier stages are therefore incorporated into the model as a reduced number of juvenile grayling entering the population. A Leslie matrix defines the number of female grayling expected to survive from one stage to the next (e.g. 1+ to 2+) measured from summer to summer (Figure 3). Matrices are used as an input at the start of the simulation.

	0+	1+	2+	3+	4+	5+	6+	7+	8+
0+				F 3+	F 4+	F 5+	F 6+	F 7+	F 8+
1+	SR 0+ 1+								
2+		SR 1+ 2+							
3+			SR 2+ 3+						
4+				SR 3+ 4+					
5+					SR 4+ 5+				
6+						SR 5+ 6+			
7+							SR 6+ 7+		
8+								SR 7+ 8+	SR 8+ 9+

Recruitment
 Survival rates

Figure 3: The Leslie matrix contains information on the age-dependent fecundity rates / recruitment (F) and age-dependent survival rates (SR). This kind of Leslie matrix is used for the calculation of the minimum viable population size (MVP) and later for the calculation of the required population size (RPS).

The current model is parametrised with a lifespan of 0+ to 8+, representing an average maximum lifespan often observed in Central European populations (Figure 4). In a number of populations however, individuals rarely reach the parameterised maximum age, and the bulk of the population is typically composed of age classes 0+ to 3+ (Droll et al., 2025). Conversely, grayling in northern Europe exhibit markedly different life-history characteristics, including a higher age of first maturation and maximum ages of up to 14+ years (Ponomarev & Zakharov, 2021). To incorporate the specific life-history characteristics, the model can be re-run using stream-specific or region-specific age-length relationships.



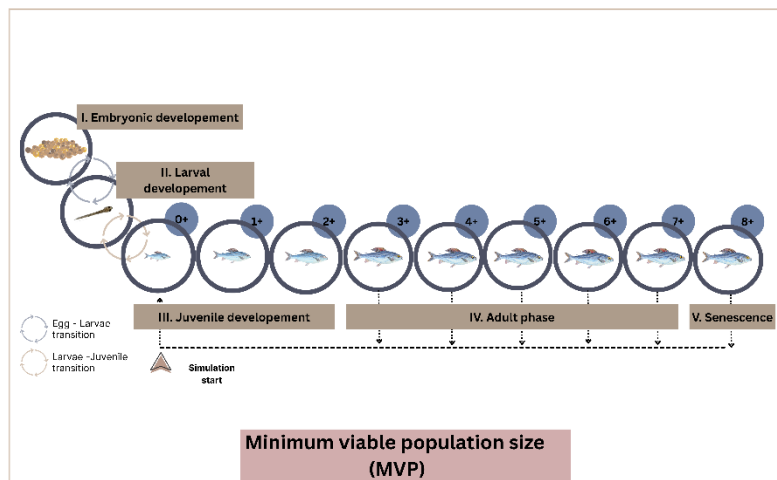


Figure 4: Structure of the population model with different age stages of grayling. Phase I: embryonic development; phase II: larval development; phase III: juvenile development (subadult); phase IV: adult phase; phase V: senescence. The arrow marks the start of the simulation.

The population model simulates the development of the age-class structure of grayling over a period of 100 years. For each initial population size, a Monte Carlo simulation (1,000 iterations) is performed to account for random demographic and environmental variability. From the 1,000 iterations, the probability of population persistence over 100 years is calculated. The lowest number of individuals with a persistence of > 0.99 is the minimum viable population (MVP). The method is based on the methodology of Wang et al. (2019).

Demographic stochasticity was captured by a density-dependent Allee effect that reduces reproductive output in small populations. The effect is implemented as a sigmoid function with five female adults representing 50 % reduction of the baseline fecundity (e.g. reflecting a reduced probability of finding a mate, Figure 5). Reproduction declines sharply (sigmoid function with $k = 2$) towards zero. These values ($N_{50} = 5$ and $k = 2$) were chosen in the model to represent a realistic, yet pronounced, reduction in reproduction in small populations. Although there is no universally accepted standard value in the literature, the biological interpretation corresponds to known mechanisms of density-dependent reproductive limitation, such as reduced mate availability or inbreeding depression (Kramer et al., 2009; Swatdipong et al., 2010).



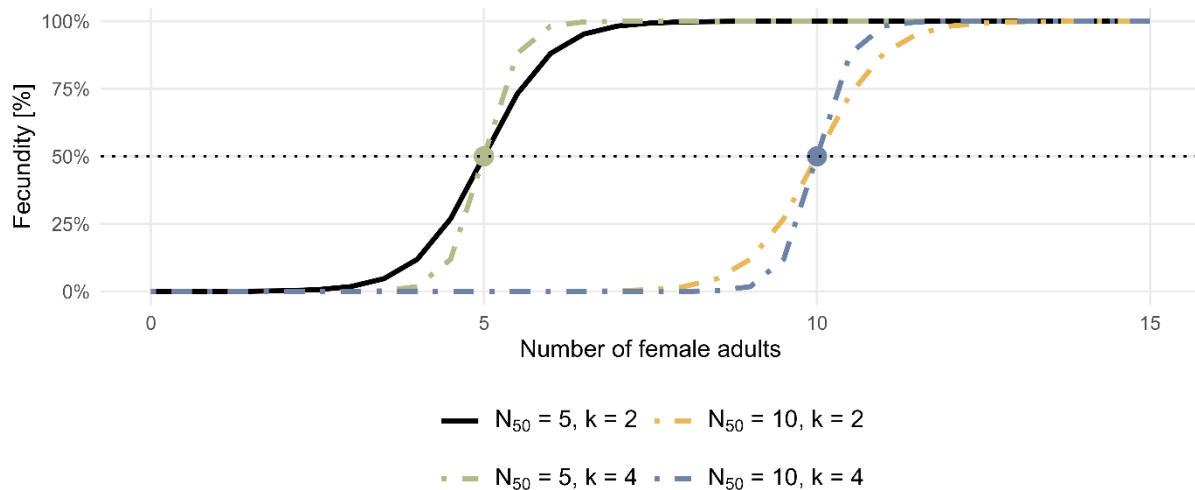


Figure 5: Depiction of the density-dependent Allee effect. The fecundity [%] is influenced by the number of adult females. N_{50} is the number of adults where fecundity is reduced by 50 %. k describes the steepness of the sigmoid function. The figure shows the Allee effect from the model (selected) and furthermore, three lines with varying numbers for N_{50} and k .

Reproduction is simulated stochastically as a Poisson process: the actual number of juveniles produced per year varies around the expected sum of the fecundity of all adult individuals. The standard deviation is approximately the square root of the expected value, so smaller populations experience proportionally larger fluctuations than larger populations (Figure 6).

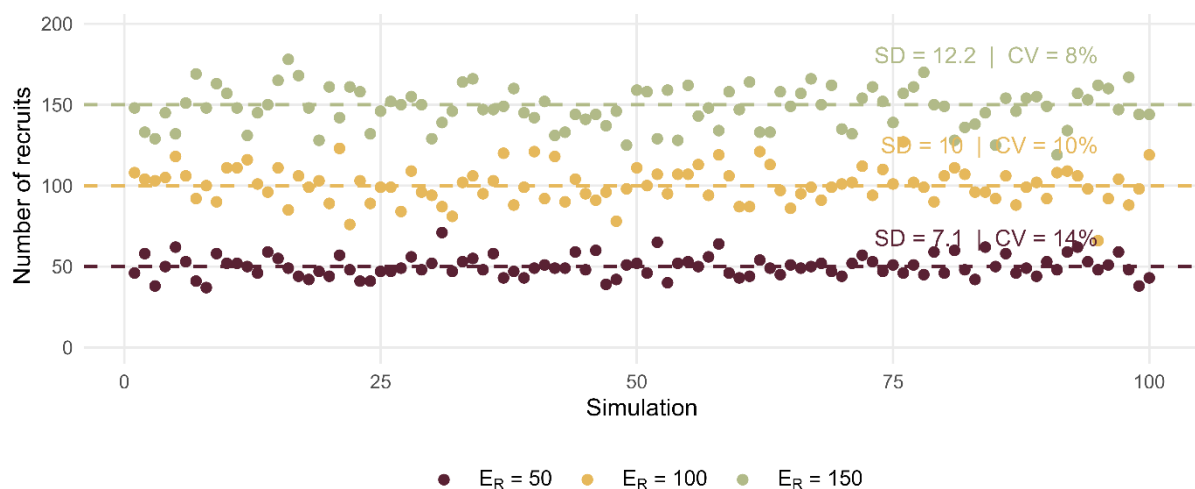


Figure 6: Illustration of demographic stochasticity in recruitment in 100 simulations. Each point represents one simulated year, with actual recruit numbers drawn from a Poisson distribution around the expected value (E_R , expected recruits). The recruitment over 100 simulated years for three population sizes (small: $E_R = 50$, medium: $E_R = 100$, large: $E_R = 150$) is depicted, dashed lines indicate the expected value. Standard deviation (SD) and the coefficient of variation (CV) are calculated for the three values for expected recruits. With decreasing population size, the coefficient of variation increases, showing that smaller populations experience proportionally larger stochastic fluctuations in annual recruitment. E_R values (50, 100, 150) are illustrative only and do not reflect actual recruitment rates in the model, which depend on age-specific fecundity and the number of adult females present in each time step.



Fecundity and survival rates are not always constant in natural systems; due to environmental factors, they vary from year to year. Environmental stochasticity was modelled at two levels: fecundity was subject to lognormal variation, reflecting interannual variation in spawning success and female condition. Annual survival rates were drawn from a Beta distribution at each time step, capturing natural environmental fluctuations in survival ($\text{var}_{\text{surv}} = 10$). 'Var_{surv}' describes the variability in the survival rates. Figure 7 shows the survival probability around a fixed survival rate. Depending on the value of the parameter 'var_{surv}' the fluctuations around the fixed rate differ. Increasing parameter values reduce variance around the mean representing less environmental stochasticity.

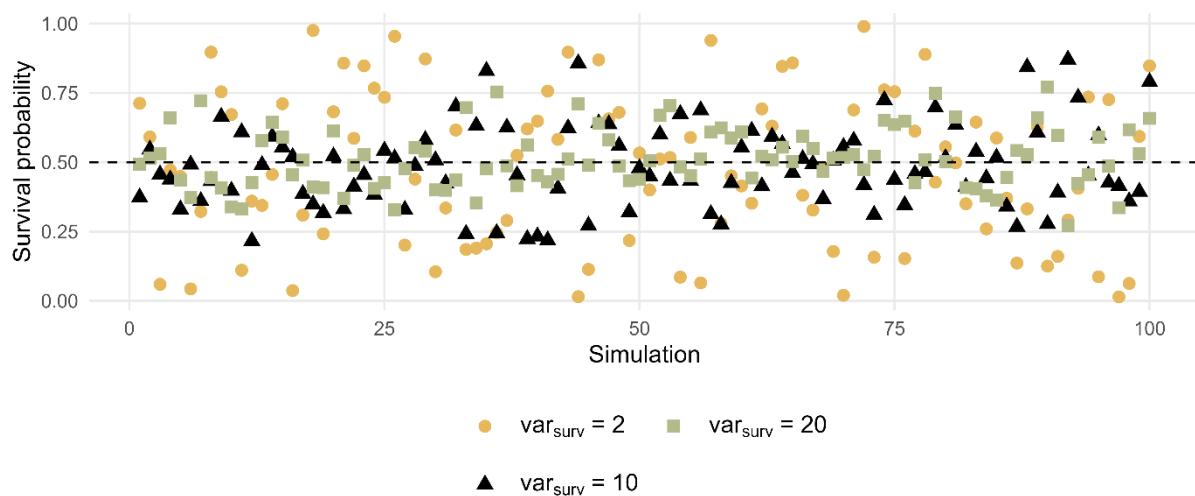


Figure 7: Illustration of simulated survival probabilities in 100 simulations generated from a Beta-distributed stochastic model of environmental variability. Each point represents the survival of one simulated year with a given environmental variability ($\text{var}_{\text{surv}} = 2, 10, 20$). The Beta distribution is parameterised by a fixed mean survival probability (0.75) illustrated by the dashed line. Increasing values reduce variance around the mean.

In addition, extreme events occurring irregularly every 20–25 years temporarily reduce survival and reproductive rates, representing episodic disturbances such as heat waves, floods, or algal blooms. Extreme events are implemented as additional multiplicative reductions and applied at a single time step per simulation run. The timing of each event is drawn stochastically prior to the time loop, with return intervals of 25 years for flow regime disturbances and 20 years for temperature and clogging disturbances, ensuring ecologically meaningful event frequencies across the 100-year simulation horizon (Table 2, implementation in the model “EE” (extreme event)).

The minimum viable population size for optimal habitat conditions or pristine conditions in the model is 1176 individuals (Figure 8). The highest proportion is in the age class 0+.



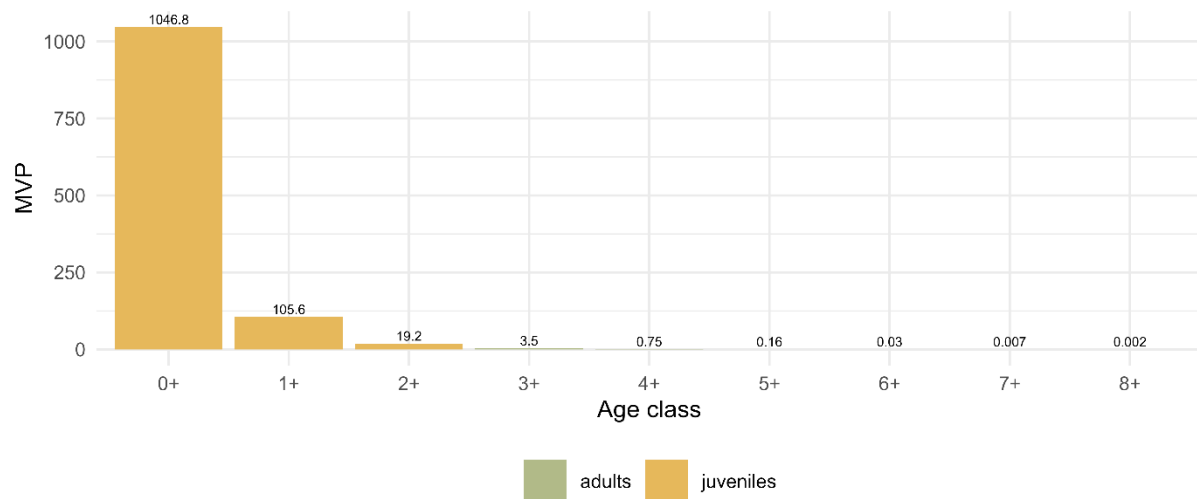


Figure 8: The minimum viable population (MVP) size derived from the population model across age classes (0+ to 8+). Bars show the stable age distribution derived from the population model. Juvenile stages (0+ to 2+) are highlighted orange, adult stages (3+ to 8+) are coloured green. Numerical labels indicate rounded MVP values for each age class.

3. Estimation of required population size (RPS)

Grayling densities are influenced by a variety of environmental stressors and prevailing habitat stressors can reduce fecundity and lead to an increase in age-specific mortality rates. Mortality rates are age-specific; stressors that affect the quality of spawning habitats primarily affect the larval stages, whereas predation primarily affects adult or larger grayling. To identify the relevant stressors, we first mapped all stressors which directly or indirectly influence grayling abundance based on literature research (supplement S 3). Thereafter, we classified the stressors and assigned them to main groups (Figure 9). The stressors flow regime, temperature, hydromorphological quality, clogging of the gravel interstices (clogging), predation and angling are incorporated into the model by adjusting survival and reproduction rates in a Leslie matrix (Figure 10 and Figure 11). In total, the RPS for 720 stressor combinations was simulated (supplement S 4).

Since there are chronic or permanent stressors and punctual or short-term stressors like extreme events, the two different stressor types with different effects were implemented in the model. Chronic stressors include habitat degradation such as clogging, which will reduce fecundity. In addition, predation and angling acts as a chronic stressor by continuously reducing survival rates. The extreme events include punctual or short-term stressors such as one hot summer or a single eutrophication



event (algal bloom with subsequent clogging). Therefore, the model is additionally equipped with the capability to simulate extreme events. These occur with a certain probability, act upon different life stages, reducing fecundities or survival rates.

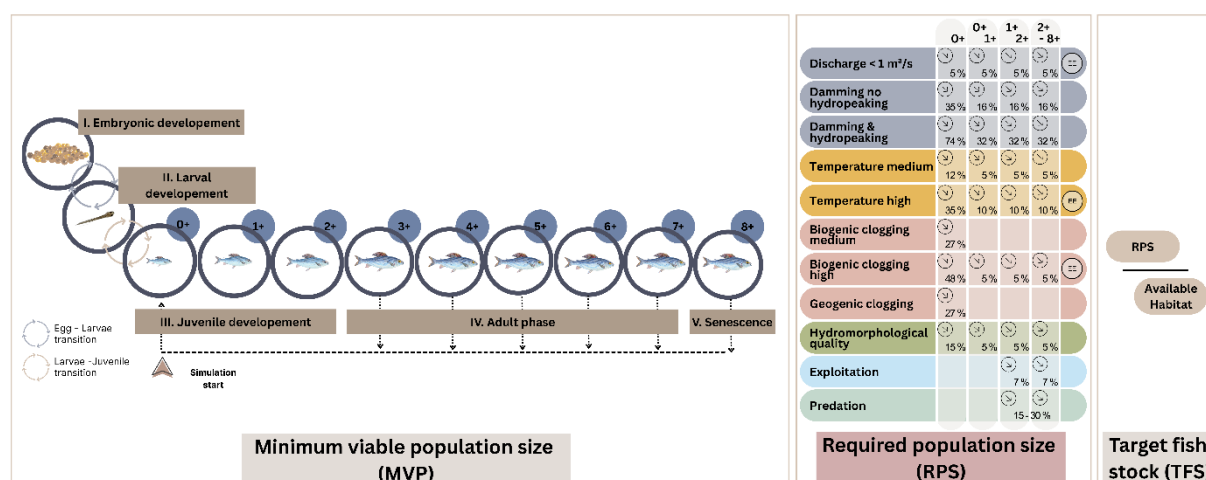


Figure 9: Structure of the population model to calculate the minimum viable population size (MVP) and required population size (RPS) with the different stressors reducing fecundity and survival rates. Stressors reduce survival rates by five to 74 %. Some stressors include additional extreme events (EE):

To assess RPS we used the two main stressors flow regime and temperature stressors leading to 12 possible main stressor combinations (Part A, Figure 10). These main combinations are followed sequentially by the specific stressors clogging, habitat structure, as well as exploitation and predation stressors (Part B, Figure 11). All stressors exert a chronic effect on survival rates (SR = survival rate; CS = chronic effect). For some stressors, additional effects from extreme events are also considered (EE = extreme event). The effects of the main stressors on fecundity and survival rates are summarised in Table 2.

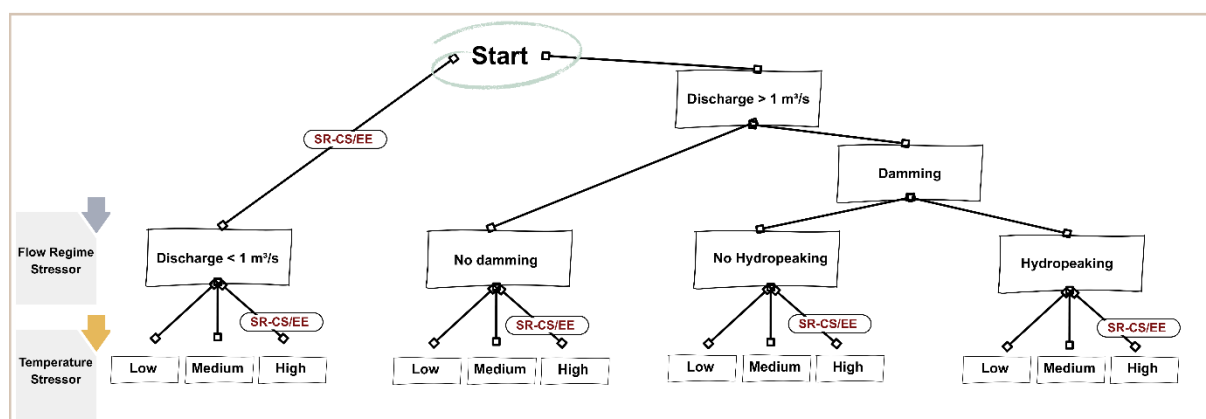


Figure 10: Flowchart of the main stressors and combinations part A. SR = survival rates, CS = chronic stressor, EE = extreme event.



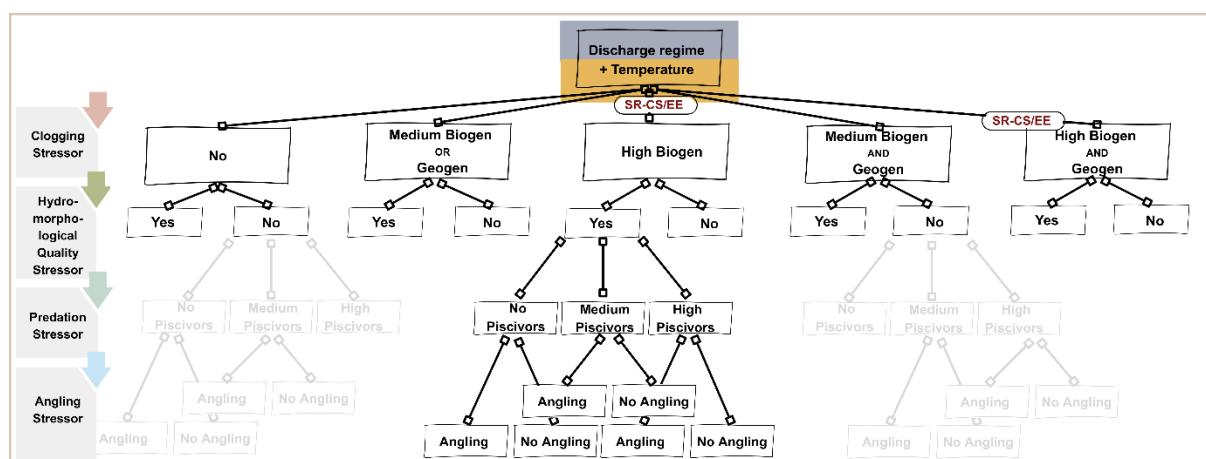


Figure 11: Flowchart of the main stressors and combinations part B. The 12 combinations of the flow regime and temperature stressors result in further combinations of the clogging stressor, hydromorphological quality stressor, predation stressor and angling stressor.



Table 2: Overview of the effects of the main stressors flow regime (1), temperature (2), clogging (3), hydromorphological quality (4), predation (5) and angling (6) on fecundity and survival rates. SR = survival rates, CS = chronic stress, EE = extreme event. For the combination of medium biogenic clogging and geogenic clogging, the reproduction rate is reduced to 58.4 %. For the combination of high biogenic clogging and geogenic clogging, the reproduction rate is reduced to 24.5 %. Extreme events occur every 20 years for temperature and clogging and all 25 years in the flow regime scenarios.

Stressors values	Threshold	Ecological effects	Implementation in the model
1a.) Low discharge stressor for small streams	< 1 m ³ /s discharge	Chronic temperature stress, extreme events	CS: 5 % reduction of fecundity and all survival rates (vom Berge et al., 2025) EE: 25 years, 50 % reduction of fecundity and all survival rates
1b.) Damming without hydropeaking	Yes	Temperature stress	CS: Hatching rates reduced by 34,81 % (Rosenau et al., 2025) CS: Subadult and adult survival reduced by 10 %
		Turbine passage mortality	CS: Subadult and adult reduction by 6.1 % (Zitek et al., 2025)
1c.) Damming with hydropeaking	Yes	Temperature stress	CS: Hatching rates reduced by 34,81 % (Rosenau et al., 2025) CS: Subadult and adult survival reduced by 10 %
		Displacement, stranding of fish larvae	CS: Survival fry reduced by 60 % (Schmutz et al., 2015)



		Fluctuations stress subadult and adult fish	CS: Subadult and adult survival reduced by 20 %, magnitude estimated (Pinter et al., 2025)
		Turbine passage mortality	CS: Subadult and adult reduction by 6.1 % (Zitek et al., 2025)
2.) Temperature stressor "low"	< 11 °C annual median for Germany (threshold values vary depending on geographical location)	-	-
2.) Temperature stressor "medium"	11 – 14 °C annual median for Germany (threshold values vary depending on geographical location)	Stress induced by elevated temperatures	CS: Hatching rates reduced by 11,89 % (Rosenau et al., 2025) CS: Juvenile, subadult and adult survival reduced by 5 % (vom Berge et al., 2025)
2.) Temperature stressor "high"	> 14 °C annual median for Germany (threshold values vary depending on geographical location)	Stress induced by high temperatures	CS: Hatching rates reduced by 34,81 % (Rosenau et al., 2025) CS: Juvenile, subadult and adult survival reduced by 10 % EE: 20 years, 50 % mortality of all age stages
3a.) Biogenic clogging "medium"	Total phosphorous > 0.10 mg/L annual median for German streams OR	Reduced embryo survival due to clogging	CS: Egg survival reduced by 27 % (Haugen, 2000)



	Orthophosphate > 0.07 mg/L annual median for German streams (OGewV, 2016)		
3a.) Geogenic clogging	Agriculture cover catchment > 20 % (Stein et al., 2021) OR Forest cover catchment < 70 % (Stein et al., 2021) OR Degraded streambed	Reduced embryo survival due to clogging	CS: Egg survival reduced by 27 % (Haugen, 2000)
3b.) Biogenic clogging "high"	Total phosphorous > 0.30 mg/L annual median for German streams (OGewV_2016) OR Orthophosphate > 0.21 mg/L annual median for German streams (OGewV_2016)	EE: Eutrophication induced pH-fluctuations and reduced oxygen	CS: Egg survival reduced by 48 % (Hübner 2000) CS: Juvenile, subadult and adult survival reduced by 5 % EE: 20 years, 50 % reduction of fecundity and all survival rates
4.) Hydromorphological quality	EP Substrate diversity > 5 OR HP Bed Structure > 5 OR Overall assessment > 5	Inappropriate/missing spawning gravel grain sizes, decline in spawning rates	CS: Fecundity reduced by 15 % Sternecker et al. (2013) reports negative effect of streambed degradation, magnitude model assumption CS: Juvenile, subadult and adult survival reduced by 5 %



	for Germany (threshold values vary depending on available data)		
5a.) Predation piscivorous birds "medium"	Cormorant index (see chapter 6.6) > 0.04		CS: Adults reduced by 15 %
5a.) Predation piscivorous birds "high"	Cormorant index (see chapter 6.6) > 0.1		CS: Adults reduced by 30 % Note: higher predation rates up to 40 % and 72 % reported (Grohmann & Pinter, 2022; Jepsen et al., 2018)
5b.) Angling pressure	Human population density for Germany > 400 ind km ⁻²		CS: 7 % Mortality of adult fish (Havn et al., 2015)



We calculated 720 RPS for stressor combinations, out of which 620 resulted in a persistent population in the search range 10 – 1,000,000 individuals. The search range were set to 1,000,000 individuals as a maximum population size (stream with 400 km length, 50 m width would result in 2,000 ha, 500 ind ha⁻¹). Non-persistent combinations were associated with flow regime alterations (in 92 % damming with or without hydropeaking), occurred under elevated predation pressure (high or medium predation pressure in 83 %) with high biogenic and geogenic clogging (in 67 %) and elevated temperatures (medium and high temperatures in 82 %). Within this subset, habitat structure and exploitation had no consistent discriminating effect. Non-persistence was observed in both bad and good structural conditions. This indicates, that if damming and high predation pressure occurs in the same system with other stressors, the persistence of a stable grayling population is unlikely. Required population sizes estimated here can be found in supplement S 4 and are ready to be used for the calculation of target fish stocks. However, if appropriate, the parameters for the estimation of the required population sizes can be adapted and the model can be re-run. The model (code) will be made accessible to all responsible authorities, the scientific community and introduced to further local stakeholders, with the goal of developing into an operational management tool.

4. Calculation of target fish stock (TFS)

While the required population size (RPS) represents the total number of individuals for the fish population without explicit habitat linkage, stakeholders typically require target metrics, such as individuals per unit area, biomass per unit area, or individuals per river kilometre (fish density). In addition, the RPS value alone does not indicate restrictions in habitat availability or longitudinal connectivity, which represent critical limiting factors in riverine systems. For this reason, in a third step of the general procedure, the RPS is projected into the available habitat (Figure 12).



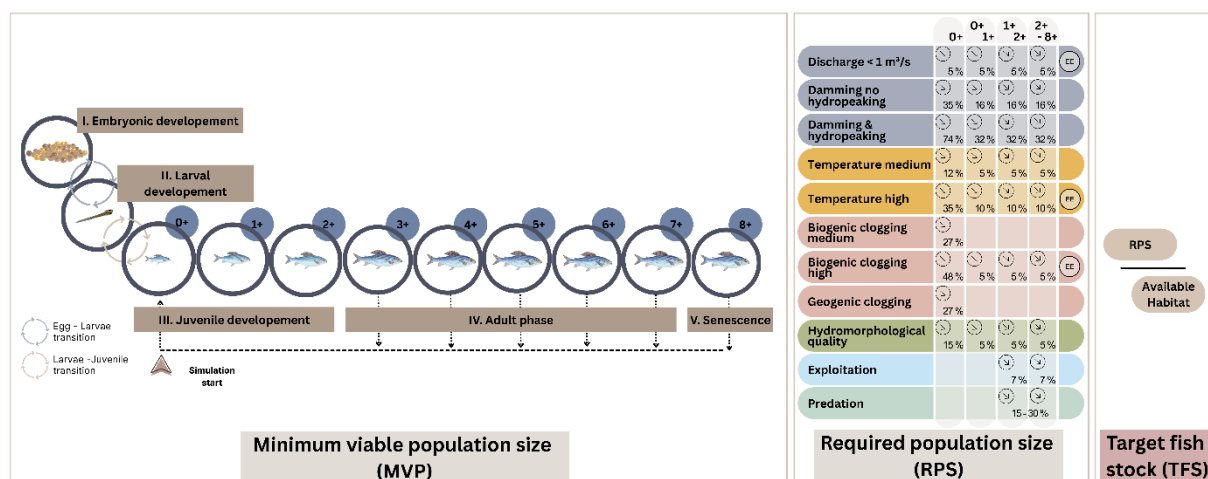


Figure 12: Structure of the population model to calculate the minimum viable population size (MVP), required population size with the effect directions on the specific age class (RPS) and target fish stock (TFS).

For the calculation of individuals per area a river stretch between two impassable barriers is delineated and converted into a surface-based habitat estimate (river width × river length). As a habitat proxy for the calculation of individuals per stream length the continuous river length can be used directly. For the assessment of each sub-catchment, the longest continuous stream stretch or the largest habitat section is used. The target fish stock is then calculated for this section as individuals per length or individuals per area (Figure 13).

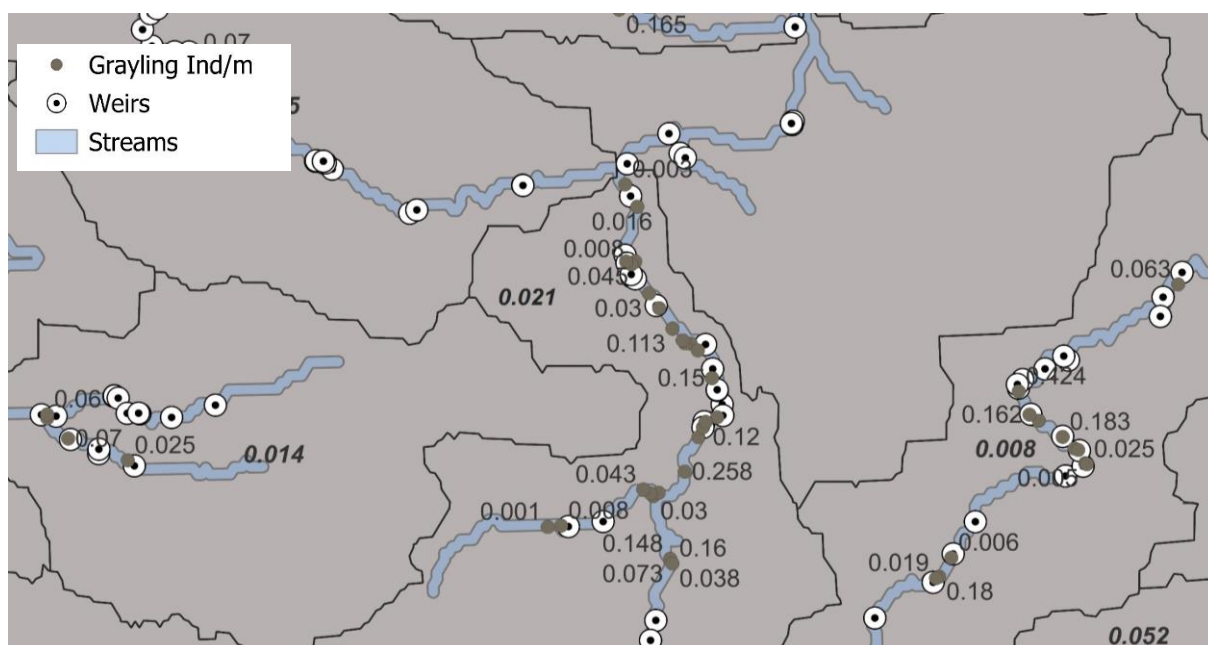


Figure 13: Excerpt from the GIS map showing the weirs and fishing surveys with positive records of grayling. The map shows in bold labelling the target fish stock (TFS) of female grayling per stream stretch in ind m⁻¹ and in regular font the grayling catches in ind m⁻¹ assuming a capture efficiency of 50 % for WFD fishing surveys.



5. Support unit for conservation status assessment

The actual assessment of conservation status is conducted at sub-catchment scale, as this spatial unit is considered most appropriate for the estimation of the required population size (RPS) using the represented population model. Sub-catchments provide a consistent and ecologically meaningful aggregation level that aligns with the model structure and the underlying habitat-based calculations. In particular, they allow for a coherent linkage between prevailing habitat stressors, required population size and available habitat. Accordingly, all analyses are performed within sub-catchment boundaries derived from the HydroBASINS dataset (Lehner & Grill, 2013). While evolutionary significant units (ESUs) are commonly discussed in the context of population genetic structuring, their identification remains scale-dependent and context-specific. In large river systems, ESUs are often assumed to correspond to major drainage basins. However, in highly modified and fragmented systems, functional population structuring may occur at smaller spatial scales. In the present study, ESUs are not explicitly defined but are considered, implicitly, through the sub-catchment-based analytical framework.

The approach presented here represents a methodological proposal and a tool intended to support authorities in their decision-making processes. We deliberately refrain from providing a strict threshold for the evaluation. At this point, we suggest a comparison between target fish stock and observed densities as a feasible approach that can serve as a broad categorization of the factors habitat and population for the conservation status assessment. Differences between the calculated target fish stock and observed fish stocks should be interpreted within this context and with caution.

5.1. *Assessment of the parameter habitat*

The parameter “habitat” is considered to unfavourable (bad) either when stressors are too strong (resulting in a non-persistent population in the model) or when stressors are strong (resulting in a high RPS) and the available habitat is limited (limited habitat area). If the model results in a persistent population but very high RPS due to intensive stressors and/or low habitat availability, the resulting theoretical target fish stock (TFS) will be very high and implausible from an ecological perspective (i.e. stocks higher than what is considered as a normal carrying capacity). Threshold values can be set with maximum densities from fishing campaigns or based on historically data.



5.2. *Assessment of the parameter population*

The assessment of the parameter “population” requires a comparison between observed density from fish survey data and the target fish stocks. In line with the concept of assessing conservation status under Article 17, the size of a population needs to exceed a defined reference population size – or be approximately equal to it (i.e. less than 5 % below) – to achieve favourable conservation status. Populations falling between 5 % and 25 % below the reference population are considered near-favourable, while deficits of 26-50 % or more indicate increasingly unfavourable status (EEA, 2026). It is up to the authorities to set the reference population size. It is worth noting that the reference population size is generally larger than target fish stocks derived from the concept of minimum viable population sizes (Epstein et al., 2016). We therefore suggest to set the target values derived from the approach presented here as following: to reach the favourable conservation status the observed density has to exceed the model-derived target fish stock by at least 5 %. Populations reaching deficits of < 15 % are reaching a near-favourable status while populations reaching deficits of 16-40 % indicate an unfavourable status. In addition to the target fish stock, the population structure and age-class distribution are also important for population persistence and can be assessed with appropriate data (cohort data). If a representative stretch for the grayling (see paragraph 7) have been surveyed, the age pyramid can also be examined in line with the stable age-class distribution. The target values for juvenile fish and adult fish are shown in supplement S 4.

5.3. *Constraints in the assessment*

The assessment is only possible for catchments with confirmed grayling presence (recent or historically). If no grayling are observed in a specific sub-catchment, there are two possibilities: either the catchment does not represent a suitable habitat for grayling due to natural environmental conditions or the grayling population has gone extinct. In the first case, there is no need to assess conservation status. In the second case, the factor population would have to be ranked as C. However, using the method and data sets described here, the evaluation of the remaining catchments is not feasible. Target fish assemblage data used in WFD assessment allow for a more comprehensive assessment. If the target fish assemblage data contains grayling, a naturally suitable habitat can be assumed, and a lack of grayling observations would indicate a bad status of the population (rated as C).



6. Identification and assessment of regional stressors

6.1. *Hydrographic network*

For the calculation of the required population size (RPS) the first step is the identification of the main grayling streams in the study area. Grayling natural range in Europe extends from the British Isles and France in the west across Central Europe to the Ural Mountains in the east, and from Scandinavia in the north to the Alpine stream systems in the south (Mruk et al., 2024; Northcote, 1995). Within this range, the spatial distribution of the species is primarily governed by physical stream characteristics, most notably gradient, stream width, and the size of the catchment area (Huet, 1949). As input data, a stream network including the streams potentially inhabited by grayling is required. The data might be held by the member states, e.g. as, characterised by fish assemblage information like target fish assemblage data for WFD assessment. A stream-size-based categorisation of the watercourses was applied because target fish assemblage data were not available at the required spatial resolution for the entire study area. HydroRIVERS v10 (Lehner & Grill, 2013) is a globally consistent, vectorised line network of river reaches as part of the HydroSHEDS database. The dataset encompasses all rivers with a catchment area of at least 10 km² or a long-term average discharge of at least 0.1 m³ s⁻¹, and provides geometric attribute information including river reach length, distance from upstream headwaters, river order, and an estimate of long-term average discharge. The flow-based size order (ORD_FLOW) categorises river sections into logarithmic classes based on mean discharge. Most rivers with confirmed grayling presence in Europe fall within the orders four to six (order 4: 100 – <1,000 m³ s⁻¹; order 5: 10 – < 100 m³ s⁻¹; order 6: 1 – <10 m³ s⁻¹, Figure 14). The advantage of using HydroRIVERS is that the network directly represents all major rivers in Europe, ensuring that transboundary rivers are accurately captured.



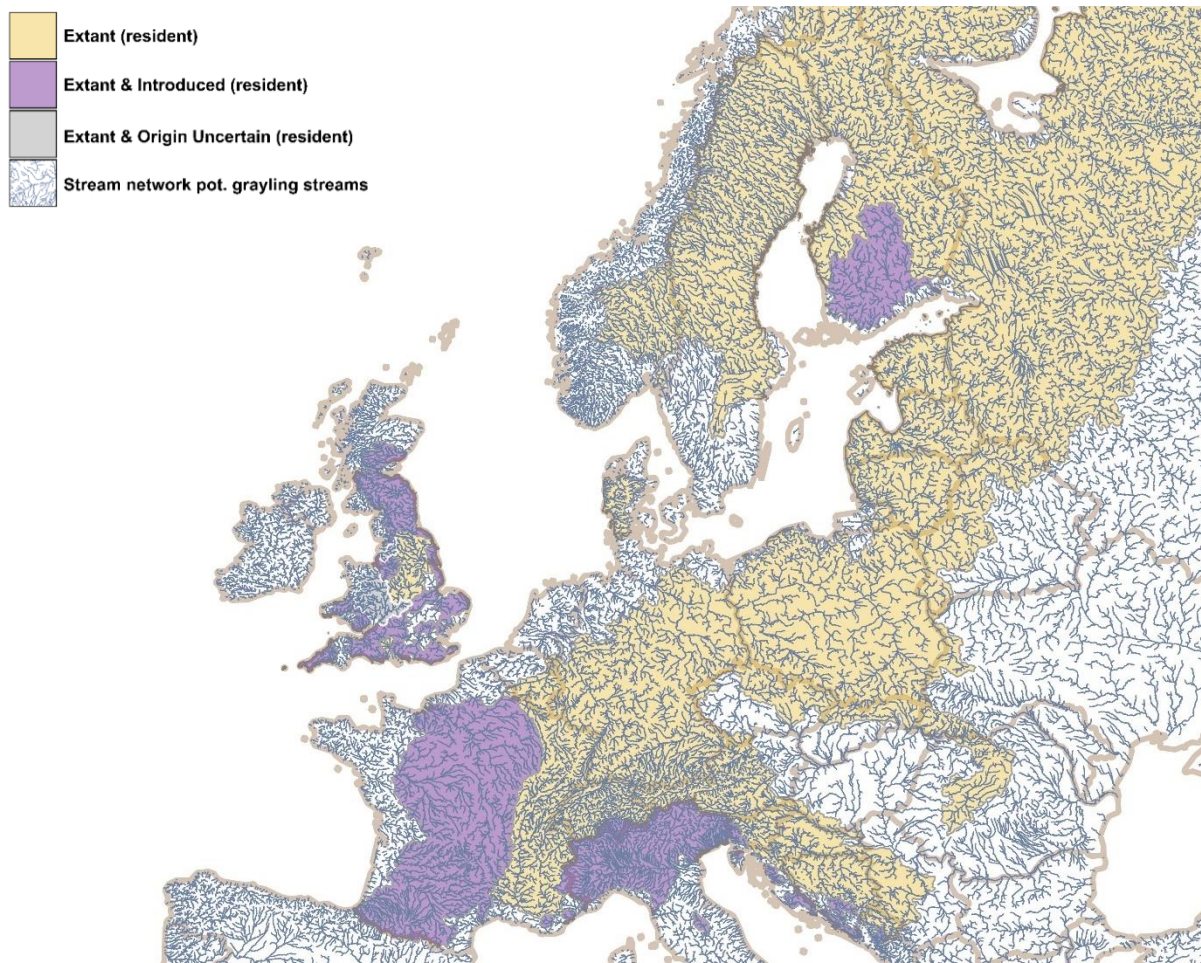


Figure 14: Stream network of the study area based on HydroRIVERS v10, filtered to flow orders 3–6 (HydroBASINS, (Lehner & Grill, 2013)), and modelled distribution range of European grayling (*Thymallus thymallus*) according to IUCN (International Union for Conservation of Nature [NatureServe and IUCN], 2022).

6.2. Flow regime stressor

Flow regime stressors are (1) discharge $< 1 \text{ m}^3 \text{ s}^{-1}$, (2) discharge $> 1 \text{ m}^3 \text{ s}^{-1}$ and no damming, (3) discharge $> 1 \text{ m}^3 \text{ s}^{-1}$, damming without hydropowering and (4) discharge $> 1 \text{ m}^3 \text{ s}^{-1}$, damming and hydropowering. However, the subgroup “small streams” ($< 1 \text{ m}^3 \text{ s}^{-1}$) represent marginal distribution areas of grayling, classification is straightforward using flow order 7. Assessing the presence of the stressor (3) discharge $> 1 \text{ m}^3 \text{ s}^{-1}$, damming without hydropowering, which induces temperature stress as well as turbine-induced mortality, is challenging due to limited data. The best available data for Europe are the Amber Barrier Atlas (AMBER Consortium, 2020). However, determining to what extent weirs in the rivers cause significant habitat alterations is problematic with the publicly available data. We propose that, in the absence of more detailed information on flow regime, stream sections with a distance of less than 1 km between barriers (weirs, dams) are classified as affected by the stressor “(3) damming



without hydropeaking” (Mielach et al., 2015). This threshold is moreover based on estimated backwater lengths for grayling streams, with typical bed slopes combined with characteristic impoundment heights of 0.5-2 m resulting in backwater zones of up to 800 m per structure. In stream stretches with lengths below 1 km, particularly at lower gradients, backwater zones of consecutive structures overlap, leaving no free-flowing reach with natural thermal and hydraulic characteristics (Table 3).

Table 3: Calculated backwater lengths (L_b) for grayling streams (width and slope, Huet, 1949). For an initial rough estimate of the backwater length, a purely geometric approach was applied. However, this approach neglects hydrodynamic effects and therefore serves only as a linear upper-bound estimate of the static backwater extent. $L_b \approx \Delta h / I \text{ ‰} * 1000$.

Stream width [m]	Slope ‰ (I)	$\Delta h = 0.5 \text{ m}$	$\Delta h = 1.0 \text{ m}$	$\Delta h = 2.0 \text{ m}$
1-5 m	3-7.5			
	3	33	167	333
	5	20	100	200
	7.5	13	67	133
5-25 m	2-6			
	2	50	250	500
	4	25	125	250
	6	17	83	167
25-100 m	1.25-4.5			
	1.25	80	400	800
	2.50	40	200	400
	4.50	22	111	222

As hydropeaking (4) information is often not available in existing barrier databases, such information must be collected separately. However, it is expected to be easier to assess for the state agencies, which will be responsible for evaluating conservation status.

6.3. Temperature stressor

Grayling are adapted to their specific thermal habitat (Junge et al., 2011; Thomassen et al., 2011). In alpine regions they are presumably adapted to lower temperatures compared to grayling in warmer regions like the low mountainous regions in the middle of Germany for example. Temperature thresholds need to be set for the different geographical regions. To classify temperature stress for Rhineland-Palatinate for example currently annual medians can be used to classify the streams in groups



with temperature stressor low, temperature stress medium and temperature stress high. Cluster analysis of data from grayling streams in Rhineland-Palatinate (Landesamt für Umwelt Rheinland-Pfalz, 2025) shows three clusters (Figure 15) with mean summer temperature ranging between 13.3–13.8 °C for the cold cluster, 16.6–18.6 °C for the intermediate cluster, and 19.3–20.2 °C for the warm cluster (Figure 16). These thresholds could either be used as regional threshold values for summer conditions, or it could be examined whether the streams under evaluation can be assigned to distinct clusters (temperature stressor low, medium, high).

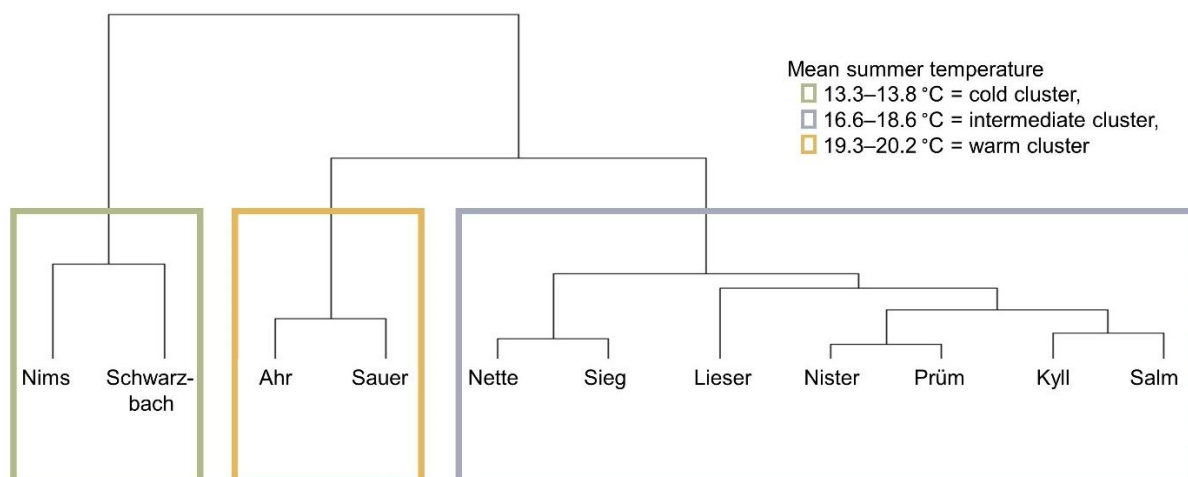


Figure 15: Stream clustering with summer temperatures (mean values). Stations Ahr, Bad Neuenahr (1587); Kyll, Mündung; Lieser, bei Üdersdorf; Nette, Pegel Nettegut; Nims bei Lasel; Nister, Mündung (1896); Prüm, Irrel; Salm, Mündung; Sauer, Mündung (RLP and LUX); Schwarzbach, Biebertmühle (0936); Sieg, Mundersbach. 2020-01-01 till 2024-12-31 (Landesamt für Umwelt Rheinland-Pfalz, 2025).

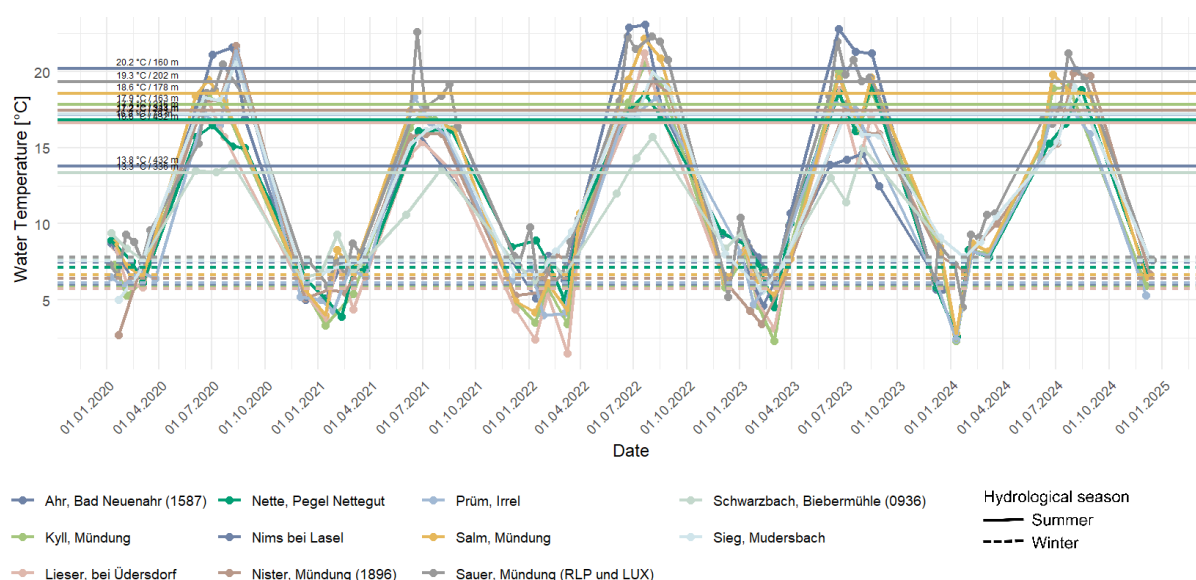


Figure 16: Temperature curve for the top measuring stations (most measurements taken between 2020 and 2025). The upper line depicts the mean values for summer months, the dashed line shows the mean winter temperatures (Landesamt für Umwelt Rheinland-Pfalz, 2025).





To estimate temperature stress, continuous data allowing the calculation of number of days above a certain threshold or maximum values would be best. However, usually only monthly single-point measurements are available for streams and small rivers from the member states. Such point measurements are still suitable for a coarse classification of stream temperature regimes. To somewhat reduce the probability of underestimating summer temperatures, only sites with at least 12 temperature measurements from the years 2020–2025 should be included for the evaluation.

6.4. Clogging stressor

Streambed clogging is induced by both geogenic processes (fine sediment input) and biogenic processes (accumulation of dead algal biomass). For this reason, threshold values for land use and nutrient concentrations were defined to describe clogging (Table 2, S 5). Land use for Europe can be derived from the CORINE Land Cover (Figure 17) and nutrient concentrations are monitored by water quality measurements from state monitoring programmes and should be available for each member state.

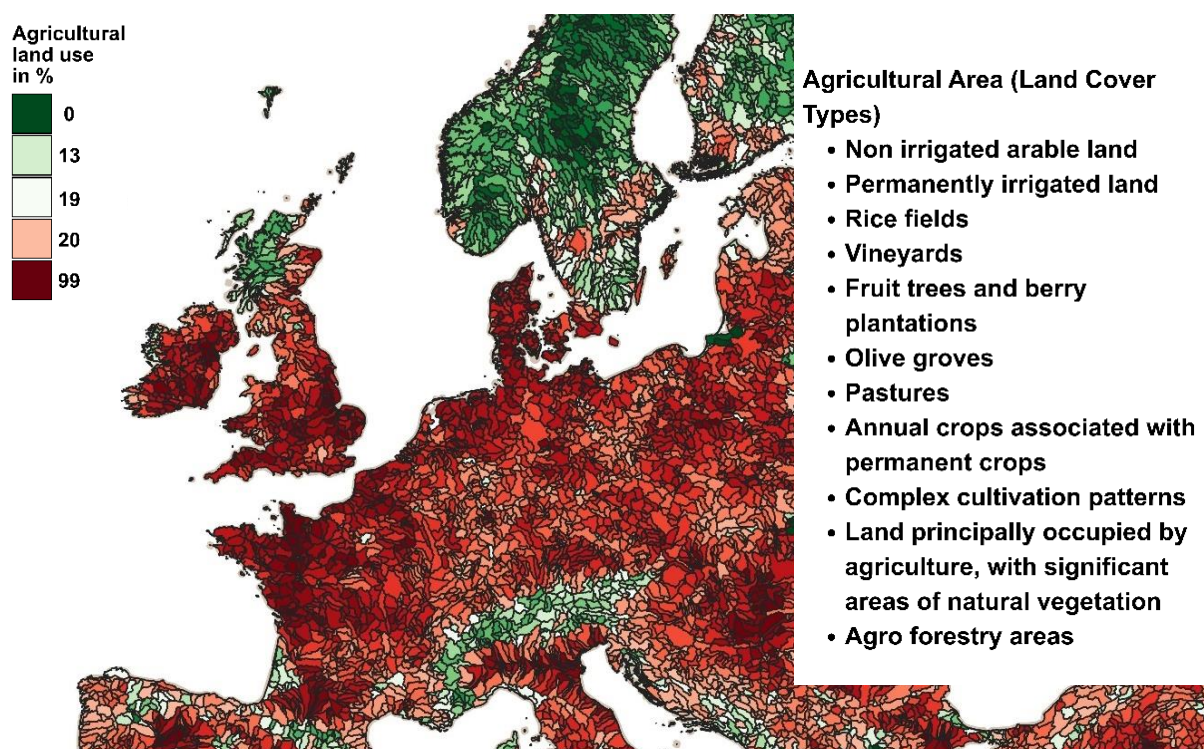


Figure 17: Clogging stressor for the sub-catchments in Europe based on the percentage of agricultural land use in percent. Red colour shows sub-catchments with high proportion of agricultural land use, green colour shows sub-catchments with a lower proportion of agricultural land use. The clogging stressor is set "geogen clogging" with agriculture cover catchment > 20 % (Stein et al., 2021).





6.5. Hydromorphological quality stressor

To estimate habitat deterioration, data from habitat quality assessments can be used. Under the Water Framework Directive there have been habitat quality mappings of the hydromorphology in the member states. In Austria, for example, channel morphology is assessed in five classes based on bank dynamics and bed dynamics. In Denmark, pressure-based hydromorphological metrics are used, which can be applied for assessment purposes. For Germany the main parameter “bed structure” from the seven-level structural quality classification can be used. Structure was assessed at the sub-catchment scale (Figure 18). It should be noted that sections not mapped (= 0) must be treated as NA. The threshold for the quality mapping in Germany was set at ≥ 5 (Table 2Table 1), describing a highly altered to extremely altered / anthropogenically degraded habitat structure. The available datasets differ slightly between countries so the thresholds have to be set by the different member states.

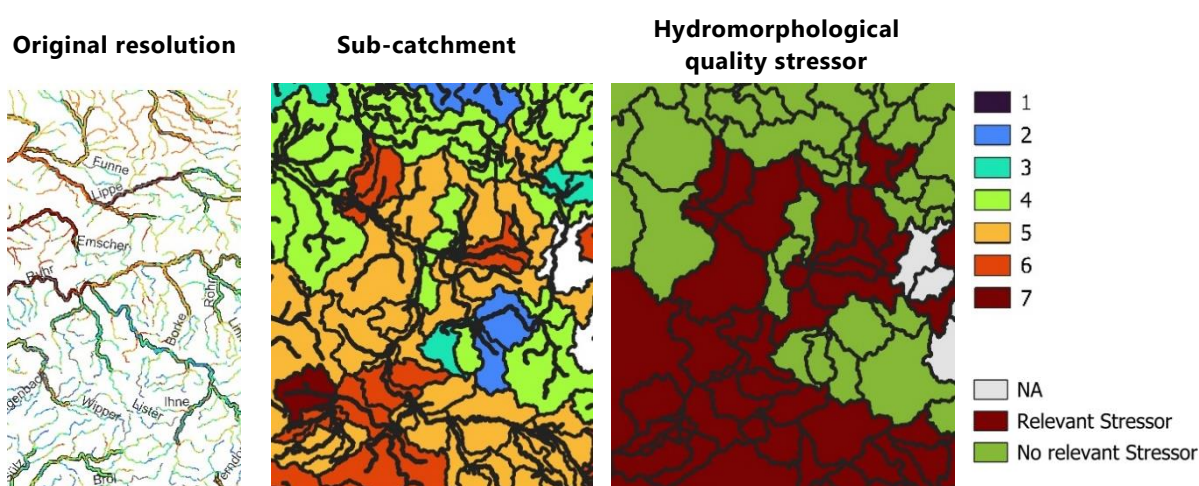


Figure 18: Derivation of the hydromorphological quality stressor based on bed structure, classification at high spatial resolution. Structural quality was assessed at sub-catchment scale with the area-weighted median of structural quality values. The resulting metric was then evaluated against the threshold ≥ 5 .

6.6. Predation stressor

Since the cormorant is one of the most effective and abundant avian predators for fish in Europe, we suggest using cormorant densities as a proxy for predation pressure. European-wide datasets of cormorant densities allowing the calculation of cormorant predation pressure are not available. We therefore suggest using cormorant observations from the eBird app (Cornell Lab of Ornithology, 2025). It is depicted here for Germany (January 2020– December 2025, Figure 19) and was used to estimate predation pressure for this example. All observations within the catchments of the grayling streams were included, not only observations directly at the shores of the respective stream, because cormorants are known to fly considerable distances to their



feeding habitats. In total, the eBird data set contains 98,927 cormorant observations (points), with counts reported for 87,305 sightings (Figure 19).

However, the use of citizen science data from public apps entails the risk of reflecting observer activity (e.g. along hiking trails) or areas where birds are frequently reported. To reduce this bias somewhat, the ratio of cormorant observations to total bird observations was calculated for each sub-catchment (Figure 19), to estimate the probability of cormorant observations.

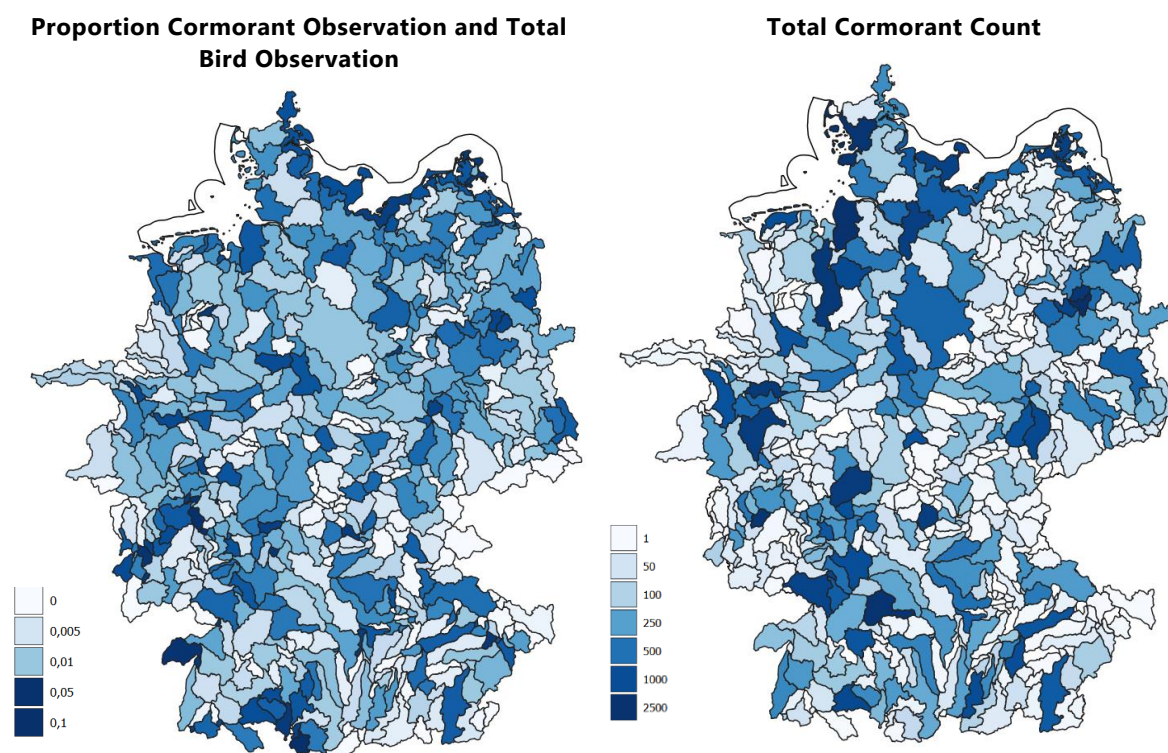


Figure 19: Overview of cormorant observations as mean for sub-catchments in Germany. Depicted as proportion of cormorant sightings relative to total sightings (left) and the total count of cormorants (right).

Since cormorant densities vary between regions, this observation probability alone might not represent a suitable proxy for predation pressure, which was indicated by the lack of relationship between cormorant counts and the proportion of cormorant observation (Figure 20). To also account for population size, we therefore calculated a weighted index for the predation pressure stressor (Figure 21). This index combines the relative frequency of cormorants in all bird sightings (proportion) with the observed count (Formula 1). To normalize cormorant counts the counts were logarithmically transformed and missing cormorant count values were replaced with 0.

Cormorant index

$$= \text{Proportion Cormorant} \times \ln(1 + \text{Cormorant Count}) \quad (1)$$



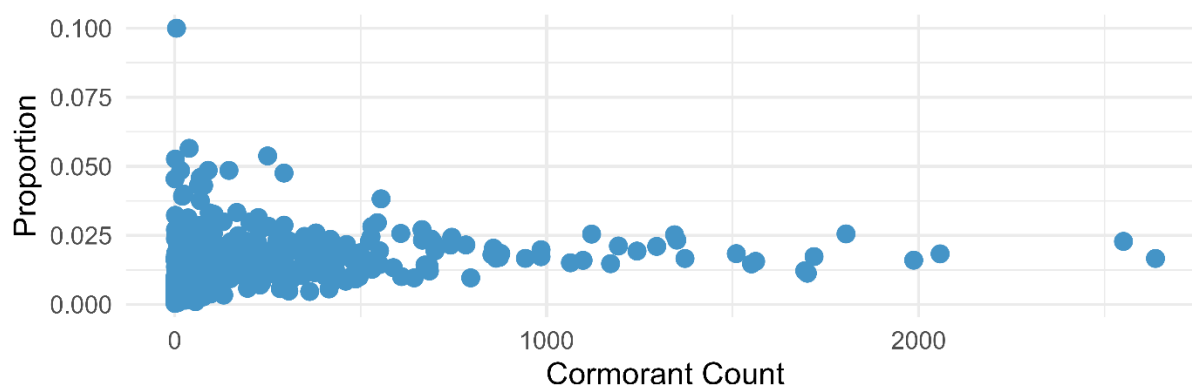


Figure 20: Comparison between the Proportion of Cormorant Observation (Proportion Cormorant Observation and Total Bird Observation) and Cormorant Counts.

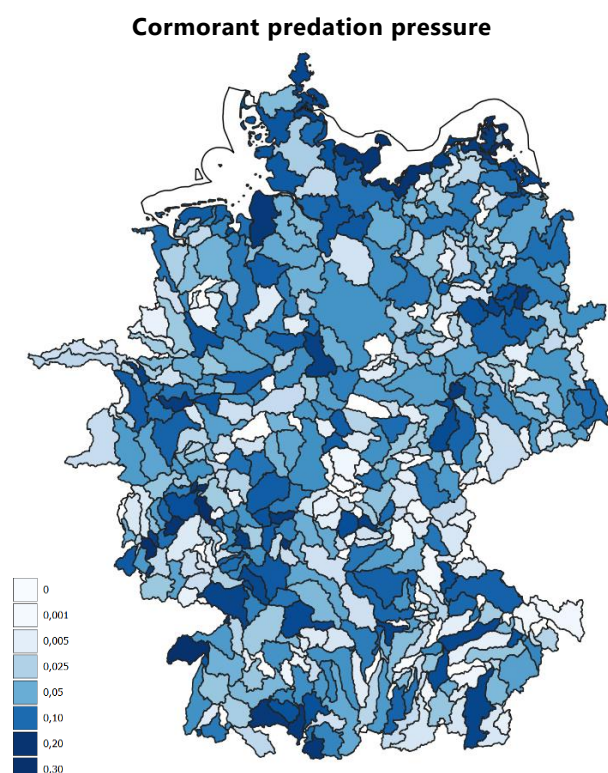


Figure 21: Geographical distribution of cormorant predation pressure index used for the model, derived from eBird data as: $\text{Cormorant Counts} / \text{Total Bird Counts} \times \ln(1 + \text{Cormorant Count})$.



6.7. *Angling stressor*

Besides cormorant predation, angling can exert relevant pressure to grayling populations (Näslund et al., 2005). State agencies often have information and data on fishing license sales, so they are able to evaluate local fishing intensity. Currently no comprehensive Europe-wide overview of angling pressure exists. The systematic collection and centralised reporting of such data is therefore strongly encouraged, as it would considerably improve the accuracy of future model assessments. Where local angling pressure data are unavailable, fishing pressure can be approximated on the basis of local human population density, under the assumption that angling intensity scales with population density.

6.8. *Additional stressors*

The stressor selection implemented in the present model reflects the most prevalent conditions of central European river systems. The framework is, however, not limited to this context – additional stressors can be incorporated to represent the stressors of other biogeographical settings.

- Acidification-related pressures: In Scandinavian river systems for example, the simultaneous presence of aluminium and iron in acidic waters is highly toxic to early life stages of grayling, causing disturbed ion regulation, gill damage, and mortality rates of up to 90 % of newly hatched grayling and 69 % of sub adults (Vuorinen et al., 1998). This stressor could be included as an additional main stressor, when assessing Scandinavian grayling conservation status.
- Severe riverbed clogging due to bedload sediment imbalance: In alpine river systems, the sediment regime is inherently dynamic, characterised by episodic high-energy bedload transport events driven by snowmelt and torrential rainfall. Anthropogenic modifications — including impoundment, channelisation, and gravel extraction — disrupt this natural sediment continuity, leading to fine sediment accumulation and severe clogging of the hyporheic zone (Hauer et al., 2020). Mortality rates potentially exceed those assumed for clogging observed in non-alpine regions. In addition to the existing five categories of clogging, a sixth category could be introduced for extreme clogging caused by bedload sediment imbalance.



7. Data quality, model limitation and representative data

The model is parameterised on the basis of published literature, and the values used inevitably reflect the conditions under which the underlying studies were conducted. It must be acknowledged, however, that the available literature describes the influence of habitat factors on grayling population dynamics only incompletely. As a consequence, the model contains inherent weaknesses that are a direct reflection of these gaps in the empirical knowledge base. The parameter ' var_{surv} ' describing the variability in survival rates is particularly acknowledged as a potential source of uncertainty, as local conditions may result in rates that deviate considerably from the literature-derived estimates. Results should therefore be interpreted with appropriate caution. Furthermore, the degree of connectivity between subpopulations is decisive for the Allee effect. The appropriate value of the parameter ' N_{50} ' is moreover likely to vary between study sites, as it depends partly on habitat size and connectivity. In larger or more fragmented habitats, individuals are less likely to encounter potential mates, meaning that Allee effects may become relevant at higher absolute population sizes than in small, confined reaches due to reduced reproductive efficiency in small groups (less synchronised spawning, lower fertilisation rates) or reduced protection against predation during spawning (Kramer et al., 2009). This adds a site-specific dimension to the uncertainty of ' N_{50} ' that cannot be reduced or quantified without precise knowledge of effective habitat size and barrier permeability within each sub-catchment.

To assess conservation status target fish density and observed fish densities are compared. Observed fish densities usually stem from electrofishing campaigns for monitoring purposes. The use of electrofishing data is subject to several sources of uncertainty that need careful consideration.

- Catchability: Catchability in electric fishing surveys for grayling is very low and differs greatly between the individual fishing campaigns. As a very rough estimate, catchabilities of 70 %, 50 % or 30 % can be assumed.
- Representative stretches: For grayling it is known that habitat requirements change during their life cycle. In some streams the habitat requirements of grayling in all life stages are supported in short stretches (Simon, 2008). In other streams grayling migrate upstream for spawning in spring and juveniles leave shallow habitats during their first winter (Nykänen & Huusko, 2003; Ovidio et al., 2004). The choice of fishing stretches is therefore crucial; ideally, fish densities in both adult and juvenile habitats would be assessed. If this is not possible, the assessment of conservation status can also be performed solely on the basis of



the number of 0+ fish. If there are sufficient juveniles present, it can be assumed that the adult individuals required for reproduction are also present. The method proposed here is not particularly well suited however, to assess stretches inhabited solely by adults, because it is not possible to verify that the recruitment is high enough to ensure persistence.

- Representative timing: Due to the habitat shift of grayling the choice of fishing date is important. Surveys carried out in late summer or early autumn ensure that the 0+ densities from juvenile habitats and the adult densities from adult habitats are representative. If there are data from several fishing campaigns, we suggest to use mean values for the assessment.

Ultimately, any assessment of conservation status necessarily relies on empirical data. Limitations in data quality are acknowledged as a potential concern; however, they should be regarded as a basis for cautious interpretation of results, rather than as grounds for abandoning the assessment framework entirely.



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Supplementary material

S 1: Literature data of fecundity and survival rates from the fertilisation to the survival of the fry and survival rates of subadult and adult grayling.

Rate	Value	Description
Fertilisation rate	0.6	Kucheruk et al. (2018, Aquaculture)
Egg-survival	0.90	Haugen (2000, Norwegian wild grayling, field experiments)
Yolk sack abs survival	1.00	Haugen (2000, Norwegian wild grayling, field experiments)
Survival swim up	0.97	Haugen (2000, Norwegian wild grayling, field experiments)
Survival fry	0.918	Jungwirth (1986, Aquaculture)
0+ -> 1+ (YoY)	0.3	Näslund (1992, first year survival of <i>Salmo trutta</i> , pond study)
1+ -> 2+, 2+ -> 3+	0.540	Marsh et al. (2021, subadult survival, model data)
3+ -> 4+...6+ -> 8+	0.640	T. O. Haugen (2000, Norwegian wild grayling, field experiments)
8+	0	Terminal class

S 2: Formular for calculation of the egg number based on existing data (Cove et al., 2018; Hertig, 2006) with the number of eggs (y) and the size of the fish in cm (x).

$$y = 409.375 * \exp(0.0693 * x)$$





S 3: Summary of all stressors potentially affecting European grayling (*Thymallus thymallus*) derived from literature research. The stressors are ordered according to the nine main groups of stressor types migration, flow regime, temperature, water quality, habitat suitability, predation, management and use, food and diseases. The stressors incorporated in the model are coloured. The stressors mainly controlled by stream size and habitat size are listed below the nine main stressor groups.



S 4: Calculated required population size (RPS), number of juveniles and number of adults for the 720 stressor combinations. The characteristics of the main stressors flow regime, temperature, hydromorphological quality, clogging, predation and exploitation are given in the table. RPS > 1.000.000 were non-persistent in the tested range 10-1,000,000.

Flow regime	Temperature	Hydromorphological quality	Clogging	Predation	Exploitation	RPS	RPS juvenile	RPS adult
damming	high	bad	high biogenic	high	yes	> 1,000,000		
	high	bad	high biogenic	high	no	> 1,000,000		
	high	bad	high biogenic	medium	yes	> 1,000,000		
	high	bad	high biogenic	medium	no	> 1,000,000		
	high	bad	high biogenic	no	yes	> 1,000,000		
	high	bad	high biogenic	no	no	> 1,000,000		
	high	bad	high biogenic and geogenic	high	yes	> 1,000,000		
	high	bad	high biogenic and geogenic	high	no	> 1,000,000		
	high	bad	high biogenic and geogenic	medium	yes	> 1,000,000		
	high	bad	high biogenic and geogenic	medium	no	> 1,000,000		
	high	bad	high biogenic and geogenic	no	yes	> 1,000,000		
	high	bad	high biogenic and geogenic	no	no	> 1,000,000		
	high	bad	medium biogenic and geogenic	high	yes	> 1,000,000		
	high	bad	medium biogenic and geogenic	high	no	> 1,000,000		
	high	bad	medium biogenic and geogenic	medium	yes	> 1,000,000		
	high	bad	medium biogenic and geogenic	medium	no	> 1,000,000		
	high	bad	medium biogenic and geogenic	no	yes	> 1,000,000		
	high	bad	medium biogenic and geogenic	no	no	489780	483096	6684
	high	bad	medium biogenic or geogenic	high	yes	> 1,000,000		
	high	bad	medium biogenic or geogenic	high	no	> 1,000,000		
	high	bad	medium biogenic or geogenic	medium	yes	> 1,000,000		
	high	bad	medium biogenic or geogenic	medium	no	> 1,000,000		
	high	bad	medium biogenic or geogenic	no	yes	> 1,000,000		
	high	bad	medium biogenic or geogenic	no	no	60078	59375	703
high	bad	no clogging	high	yes	> 1,000,000			
high	bad	no clogging	high	no	> 1,000,000			

damming	high	bad	no clogging	medium	yes	> 1,000,000		
	high	bad	no clogging	medium	no	> 1,000,000		
	high	bad	no clogging	no	yes	50000	49549	451
	high	bad	no clogging	no	no	16356	16202	154
	high	good	high biogenic	high	yes	> 1,000,000		
	high	good	high biogenic	high	no	> 1,000,000		
	high	good	high biogenic	medium	yes	> 1,000,000		
	high	good	high biogenic	medium	no	> 1,000,000		
	high	good	high biogenic	no	yes	> 1,000,000		
	high	good	high biogenic	no	no	> 1,000,000		
	high	good	high biogenic and geogenic	high	yes	> 1,000,000		
	high	good	high biogenic and geogenic	high	no	> 1,000,000		
	high	good	high biogenic and geogenic	medium	yes	> 1,000,000		
	high	good	high biogenic and geogenic	medium	no	> 1,000,000		
	high	good	high biogenic and geogenic	no	yes	> 1,000,000		
	high	good	high biogenic and geogenic	no	no	> 1,000,000		
	high	good	medium biogenic and geogenic	high	yes	> 1,000,000		
	high	good	medium biogenic and geogenic	high	no	> 1,000,000		
	high	good	medium biogenic and geogenic	medium	yes	> 1,000,000		
	high	good	medium biogenic and geogenic	medium	no	> 1,000,000		
	high	good	medium biogenic and geogenic	no	yes	85210	84176	1034
	high	good	medium biogenic and geogenic	no	no	18422	18189	233
	high	good	medium biogenic or geogenic	high	yes	> 1,000,000		
	high	good	medium biogenic or geogenic	high	no	> 1,000,000		
	high	good	medium biogenic or geogenic	medium	yes	> 1,000,000		
	high	good	medium biogenic or geogenic	medium	no	409962	405910	4052
	high	good	medium biogenic or geogenic	no	yes	37510	37120	390
	high	good	medium biogenic or geogenic	no	no	7500	7419	81
	high	good	no clogging	high	yes	> 1,000,000		
	high	good	no clogging	high	no	> 1,000,000		
	high	good	no clogging	medium	yes	277606	275490	2116
	high	good	no clogging	medium	no	46808	46436	372
	high	good	no clogging	no	yes	18756	18599	157
	high	good	no clogging	no	no	7808	7740	68
	low	bad	high biogenic	high	yes	> 1,000,000		
	low	bad	high biogenic	high	no	> 1,000,000		
	low	bad	high biogenic	medium	yes	> 1,000,000		
	low	bad	high biogenic	medium	no	762564	754616	7948



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damming	low	bad	high biogenic	no	yes	42676	42208	468
	low	bad	high biogenic	no	no	13024	12875	149
	low	bad	high biogenic and geogenic	high	yes	> 1,000,000		
	low	bad	high biogenic and geogenic	high	no	> 1,000,000		
	low	bad	high biogenic and geogenic	medium	yes	> 1,000,000		
	low	bad	high biogenic and geogenic	medium	no	> 1,000,000		
	low	bad	high biogenic and geogenic	no	yes	> 1,000,000		
	low	bad	high biogenic and geogenic	no	no	> 1,000,000		
	low	bad	medium biogenic and geogenic	high	yes	> 1,000,000		
	low	bad	medium biogenic and geogenic	high	no	> 1,000,000		
	low	bad	medium biogenic and geogenic	medium	yes	28532	28259	273
	low	bad	medium biogenic and geogenic	medium	no	9150	9059	91
	low	bad	medium biogenic and geogenic	no	yes	5002	4950	52
	low	bad	medium biogenic and geogenic	no	no	2574	2546	28
	low	bad	medium biogenic or geogenic	high	yes	> 1,000,000		
	low	bad	medium biogenic or geogenic	high	no	193392	191913	1479
	low	bad	medium biogenic or geogenic	medium	yes	12486	12384	102
	low	bad	medium biogenic or geogenic	medium	no	7814	7747	67
	low	bad	medium biogenic or geogenic	no	yes	3928	3893	35
	low	bad	medium biogenic or geogenic	no	no	2416	2393	23
	low	bad	no clogging	high	yes	159184	158246	938
	low	bad	no clogging	high	no	53712	53382	330
	low	bad	no clogging	medium	yes	9192	9132	60
	low	bad	no clogging	medium	no	5946	5905	41
	low	bad	no clogging	no	yes	3538	3513	25
	low	bad	no clogging	no	no	2686	2666	20
	low	good	high biogenic	high	yes	> 1,000,000		
	low	good	high biogenic	high	no	> 1,000,000		
	low	good	high biogenic	medium	yes	136764	135497	1267
	low	good	high biogenic	medium	no	26750	26492	258
	low	good	high biogenic	no	yes	8592	8505	87
	low	good	high biogenic	no	no	5946	5883	63
	low	good	high biogenic and geogenic	high	yes	> 1,000,000		
	low	good	high biogenic and geogenic	high	no	> 1,000,000		
	low	good	high biogenic and geogenic	medium	yes	> 1,000,000		
	low	good	high biogenic and geogenic	medium	no	> 1,000,000		
	low	good	high biogenic and geogenic	no	yes	347340	341414	5926
	low	good	high biogenic and geogenic	no	no	21656	21271	385

damming	low	good	medium biogenic and geogenic	high	yes	271766	269611	2155
	low	good	medium biogenic and geogenic	high	no	36622	36319	303
	low	good	medium biogenic and geogenic	medium	yes	6732	6672	60
	low	good	medium biogenic and geogenic	medium	no	4154	4116	38
	low	good	medium biogenic and geogenic	no	yes	2460	2436	24
	low	good	medium biogenic and geogenic	no	no	1942	1922	20
	low	good	medium biogenic or geogenic	high	yes	65016	64574	442
	low	good	medium biogenic or geogenic	high	no	18694	18562	132
	low	good	medium biogenic or geogenic	medium	yes	6680	6629	51
	low	good	medium biogenic or geogenic	medium	no	3986	3955	31
	low	good	medium biogenic or geogenic	no	yes	2420	2400	20
	low	good	medium biogenic or geogenic	no	no	1980	1963	17
	low	good	no clogging	high	yes	24938	24802	136
	low	good	no clogging	high	no	16022	15931	91
	low	good	no clogging	medium	yes	5596	5562	34
	low	good	no clogging	medium	no	4378	4350	28
	low	good	no clogging	no	yes	2800	2781	19
	low	good	no clogging	no	no	2268	2252	16
	medium	bad	high biogenic	high	yes	> 1,000,000		
	medium	bad	high biogenic	high	no	> 1,000,000		
	medium	bad	high biogenic	medium	yes	> 1,000,000		
	medium	bad	high biogenic	medium	no	> 1,000,000		
	medium	bad	high biogenic	no	yes	> 1,000,000		
	medium	bad	high biogenic	no	no	66144	65348	796
	medium	bad	high biogenic and geogenic	high	yes	> 1,000,000		
	medium	bad	high biogenic and geogenic	high	no	> 1,000,000		
	medium	bad	high biogenic and geogenic	medium	yes	> 1,000,000		
	medium	bad	high biogenic and geogenic	medium	no	> 1,000,000		
	medium	bad	high biogenic and geogenic	no	yes	> 1,000,000		
	medium	bad	high biogenic and geogenic	no	no	> 1,000,000		
	medium	bad	medium biogenic and geogenic	high	yes	> 1,000,000		
	medium	bad	medium biogenic and geogenic	high	no	> 1,000,000		
	medium	bad	medium biogenic and geogenic	medium	yes	851872	843287	8585
	medium	bad	medium biogenic and geogenic	medium	no	36278	35897	381
	medium	bad	medium biogenic and geogenic	no	yes	8636	8541	95
	medium	bad	medium biogenic and geogenic	no	no	4520	4468	52
	medium	bad	medium biogenic or geogenic	high	yes	> 1,000,000		
	medium	bad	medium biogenic or geogenic	high	no	> 1,000,000		



damming	medium	bad	medium biogenic or geogenic	medium	yes	94606	93789	817
	medium	bad	medium biogenic or geogenic	medium	no	19224	19051	173
	medium	bad	medium biogenic or geogenic	no	yes	6890	6825	65
	medium	bad	medium biogenic or geogenic	no	no	3928	3889	39
	medium	bad	no clogging	high	yes	> 1,000,000		
	medium	bad	no clogging	high	no	409700	407049	2651
	medium	bad	no clogging	medium	yes	19874	19736	138
	medium	bad	no clogging	medium	no	9638	9568	70
	medium	bad	no clogging	no	yes	5402	5361	41
	medium	bad	no clogging	no	no	3912	3881	31
	medium	good	high biogenic	high	yes	> 1,000,000		
	medium	good	high biogenic	high	no	> 1,000,000		
	medium	good	high biogenic	medium	yes	> 1,000,000		
	medium	good	high biogenic	medium	no	469572	464798	4774
	medium	good	high biogenic	no	yes	37752	37348	404
	medium	good	high biogenic	no	no	10348	10233	115
	medium	good	high biogenic and geogenic	high	yes	> 1,000,000		
	medium	good	high biogenic and geogenic	high	no	> 1,000,000		
	medium	good	high biogenic and geogenic	medium	yes	> 1,000,000		
	medium	good	high biogenic and geogenic	medium	no	> 1,000,000		
	medium	good	high biogenic and geogenic	no	yes	> 1,000,000		
	medium	good	high biogenic and geogenic	no	no	> 1,000,000		
	medium	good	medium biogenic and geogenic	high	yes	> 1,000,000		
	medium	good	medium biogenic and geogenic	high	no	991538	982904	8634
	medium	good	medium biogenic and geogenic	medium	yes	22962	22748	214
	medium	good	medium biogenic and geogenic	medium	no	8144	8065	79
	medium	good	medium biogenic and geogenic	no	yes	4076	4034	42
	medium	good	medium biogenic and geogenic	no	no	2666	2638	28
	medium	good	medium biogenic or geogenic	high	yes	> 1,000,000		
	medium	good	medium biogenic or geogenic	high	no	133760	132762	998
	medium	good	medium biogenic or geogenic	medium	yes	14184	14071	113
	medium	good	medium biogenic or geogenic	medium	no	7502	7440	62
	medium	good	medium biogenic or geogenic	no	yes	4028	3993	35
	medium	good	medium biogenic or geogenic	no	no	2614	2590	24
	medium	good	no clogging	high	yes	147180	146334	846
	medium	good	no clogging	high	no	37558	37333	225
	medium	good	no clogging	medium	yes	8730	8674	56
	medium	good	no clogging	medium	no	5000	4967	33

damming	medium	good	no clogging	no	yes	3510	3485	25
	medium	good	no clogging	no	no	2582	2563	19
damming and hydropeaking	high	bad	high biogenic	high	yes	> 1,000,000		
	high	bad	high biogenic	high	no	441200	438015	3185
	high	bad	high biogenic	medium	yes	36816	36531	285
	high	bad	high biogenic	medium	no	25006	24805	201
	high	bad	high biogenic	no	yes	9108	9031	77
	high	bad	high biogenic	no	no	4766	4724	42
	high	bad	high biogenic and geogenic	high	yes	> 1,000,000		
	high	bad	high biogenic and geogenic	high	no	> 1,000,000		
	high	bad	high biogenic and geogenic	medium	yes	> 1,000,000		
	high	bad	high biogenic and geogenic	medium	no	161212	159023	2189
	high	bad	high biogenic and geogenic	no	yes	24956	24600	356
	high	bad	high biogenic and geogenic	no	no	10176	10025	151
	high	bad	medium biogenic and geogenic	high	yes	50936	50599	337
	high	bad	medium biogenic and geogenic	high	no	20530	20388	142
	high	bad	medium biogenic and geogenic	medium	yes	9376	9307	69
	high	bad	medium biogenic and geogenic	medium	no	4376	4342	34
	high	bad	medium biogenic and geogenic	no	yes	3104	3079	25
	high	bad	medium biogenic and geogenic	no	no	2740	2717	23
	high	bad	medium biogenic or geogenic	high	yes	25004	24862	142
	high	bad	medium biogenic or geogenic	high	no	19584	19468	116
	high	bad	medium biogenic or geogenic	medium	yes	7896	7846	50
	high	bad	medium biogenic or geogenic	medium	no	5080	5047	33
	high	bad	medium biogenic or geogenic	no	yes	2972	2951	21
	high	bad	medium biogenic or geogenic	no	no	2420	2403	17
	high	bad	no clogging	high	yes	24344	24233	111
	high	bad	no clogging	high	no	14672	14603	69
	high	bad	no clogging	medium	yes	6600	6567	33
	high	bad	no clogging	medium	no	4818	4793	25
	high	bad	no clogging	no	yes	3118	3101	17
	high	bad	no clogging	no	no	2974	2957	17
	high	good	high biogenic	high	yes	150192	149229	963
	high	good	high biogenic	high	no	52476	52125	351
	high	good	high biogenic	medium	yes	16136	16021	115
	high	good	high biogenic	medium	no	8396	8333	63
	high	good	high biogenic	no	yes	6252	6203	49
	high	good	high biogenic	no	no	4416	4380	36



damming and hydropeaking	high	good	high biogenic and geogenic	high	yes	> 1,000,000		
	high	good	high biogenic and geogenic	high	no	> 1,000,000		
	high	good	high biogenic and geogenic	medium	yes	86298	85256	1042
	high	good	high biogenic and geogenic	medium	no	28324	27968	356
	high	good	high biogenic and geogenic	no	yes	8512	8399	113
	high	good	high biogenic and geogenic	no	no	4962	4894	68
	high	good	medium biogenic and geogenic	high	yes	17122	17017	105
	high	good	medium biogenic and geogenic	high	no	9760	9698	62
	high	good	medium biogenic and geogenic	medium	yes	5210	5174	36
	high	good	medium biogenic and geogenic	medium	no	3690	3664	26
	high	good	medium biogenic and geogenic	no	yes	2496	2477	19
	high	good	medium biogenic and geogenic	no	no	1996	1980	16
	high	good	medium biogenic or geogenic	high	yes	14042	13968	74
	high	good	medium biogenic or geogenic	high	no	8984	8935	49
	high	good	medium biogenic or geogenic	medium	yes	4782	4754	28
	high	good	medium biogenic or geogenic	medium	no	3680	3658	22
	high	good	medium biogenic or geogenic	no	yes	2464	2448	16
	high	good	medium biogenic or geogenic	no	no	2212	2197	15
	high	good	no clogging	high	yes	15738	15672	66
	high	good	no clogging	high	no	10952	10904	48
	high	good	no clogging	medium	yes	5940	5912	28
	high	good	no clogging	medium	no	3746	3728	18
	high	good	no clogging	no	yes	2888	2873	15
	high	good	no clogging	no	no	2592	2578	14
	low	bad	high biogenic	high	yes	15274	15190	84
	low	bad	high biogenic	high	no	8588	8539	49
	low	bad	high biogenic	medium	yes	5250	5218	32
	low	bad	high biogenic	medium	no	3128	3108	20
	low	bad	high biogenic	no	yes	2978	2958	20
	low	bad	high biogenic	no	no	1860	1847	13
	low	bad	high biogenic and geogenic	high	yes	43638	43231	407
	low	bad	high biogenic and geogenic	high	no	17366	17197	169
	low	bad	high biogenic and geogenic	medium	yes	5000	4948	52
	low	bad	high biogenic and geogenic	medium	no	3514	3476	38
	low	bad	high biogenic and geogenic	no	yes	2188	2163	25
	low	bad	high biogenic and geogenic	no	no	1892	1869	23
	low	bad	medium biogenic and geogenic	high	yes	5668	5638	30
	low	bad	medium biogenic and geogenic	high	no	3706	3686	20

damming and hydropeaking	low	bad	medium biogenic and geogenic	medium	yes	2346	2332	14
	low	bad	medium biogenic and geogenic	medium	no	2058	2045	13
	low	bad	medium biogenic and geogenic	no	yes	1596	1586	10
	low	bad	medium biogenic and geogenic	no	no	1424	1414	10
	low	bad	medium biogenic or geogenic	high	yes	5132	5109	23
	low	bad	medium biogenic or geogenic	high	no	3980	3961	19
	low	bad	medium biogenic or geogenic	medium	yes	2744	2730	14
	low	bad	medium biogenic or geogenic	medium	no	2312	2300	12
	low	bad	medium biogenic or geogenic	no	yes	1768	1758	10
	low	bad	medium biogenic or geogenic	no	no	1388	1380	8
	low	bad	no clogging	high	yes	5756	5735	21
	low	bad	no clogging	high	no	4618	4601	17
	low	bad	no clogging	medium	yes	3026	3014	12
	low	bad	no clogging	medium	no	2664	2653	11
	low	bad	no clogging	no	yes	2196	2186	10
	low	bad	no clogging	no	no	1744	1736	8
	low	good	high biogenic	high	yes	9324	9276	48
	low	good	high biogenic	high	no	5918	5886	32
	low	good	high biogenic	medium	yes	3842	3820	22
	low	good	high biogenic	medium	no	3002	2984	18
	low	good	high biogenic	no	yes	2212	2198	14
	low	good	high biogenic	no	no	1778	1766	12
	low	good	high biogenic and geogenic	high	yes	13666	13548	118
	low	good	high biogenic and geogenic	high	no	8554	8477	77
	low	good	high biogenic and geogenic	medium	yes	3584	3549	35
	low	good	high biogenic and geogenic	medium	no	2702	2675	27
	low	good	high biogenic and geogenic	no	yes	1626	1609	17
	low	good	high biogenic and geogenic	no	no	1358	1343	15
	low	good	medium biogenic and geogenic	high	yes	3816	3797	19
	low	good	medium biogenic and geogenic	high	no	3178	3162	16
	low	good	medium biogenic and geogenic	medium	yes	2256	2244	12
	low	good	medium biogenic and geogenic	medium	no	1866	1855	11
	low	good	medium biogenic and geogenic	no	yes	1408	1400	8
	low	good	medium biogenic and geogenic	no	no	1176	1169	7
	low	good	medium biogenic or geogenic	high	yes	4188	4171	17
	low	good	medium biogenic or geogenic	high	no	3126	3112	14
	low	good	medium biogenic or geogenic	medium	yes	2540	2528	12
	low	good	medium biogenic or geogenic	medium	no	1952	1943	9



damming and hydropeaking	low	good	medium biogenic or geogenic	no	yes	1608	1600	8
	low	good	medium biogenic or geogenic	no	no	1432	1424	8
	low	good	no clogging	high	yes	4566	4551	15
	low	good	no clogging	high	no	4104	4090	14
	low	good	no clogging	medium	yes	2640	2630	10
	low	good	no clogging	medium	no	2108	2100	8
	low	good	no clogging	no	yes	1804	1797	7
	low	good	no clogging	no	no	1518	1512	6
	medium	bad	high biogenic	high	yes	30656	30477	179
	medium	bad	high biogenic	high	no	18784	18670	114
	medium	bad	high biogenic	medium	yes	6698	6654	44
	medium	bad	high biogenic	medium	no	4694	4662	32
	medium	bad	high biogenic	no	yes	3068	3046	22
	medium	bad	high biogenic	no	no	2594	2575	19
	medium	bad	high biogenic and geogenic	high	yes	> 1,000,000		
	medium	bad	high biogenic and geogenic	high	no	97152	96156	996
	medium	bad	high biogenic and geogenic	medium	yes	12086	11953	133
	medium	bad	high biogenic and geogenic	medium	no	5600	5536	64
	medium	bad	high biogenic and geogenic	no	yes	3494	3452	42
	medium	bad	high biogenic and geogenic	no	no	2358	2328	30
	medium	bad	medium biogenic and geogenic	high	yes	6716	6679	37
	medium	bad	medium biogenic and geogenic	high	no	4702	4675	27
	medium	bad	medium biogenic and geogenic	medium	yes	2958	2940	18
	medium	bad	medium biogenic and geogenic	medium	no	2228	2214	14
	medium	bad	medium biogenic and geogenic	no	yes	1748	1736	12
	medium	bad	medium biogenic and geogenic	no	no	1424	1414	10
	medium	bad	medium biogenic or geogenic	high	yes	8126	8087	39
	medium	bad	medium biogenic or geogenic	high	no	5010	4985	25
	medium	bad	medium biogenic or geogenic	medium	yes	3040	3024	16
	medium	bad	medium biogenic or geogenic	medium	no	2818	2802	16
	medium	bad	medium biogenic or geogenic	no	yes	2020	2008	12
	medium	bad	medium biogenic or geogenic	no	no	1696	1686	10
	medium	bad	no clogging	high	yes	6558	6533	25
	medium	bad	no clogging	high	no	5156	5136	20
	medium	bad	no clogging	medium	yes	3470	3455	15
	medium	bad	no clogging	medium	no	2868	2855	13
	medium	bad	no clogging	no	yes	2506	2494	12
	medium	bad	no clogging	no	no	1960	1951	9

damming and hydropeaking	medium	good	high biogenic	high	yes	19146	19043	103
	medium	good	high biogenic	high	no	8600	8552	48
	medium	good	high biogenic	medium	yes	4832	4803	29
	medium	good	high biogenic	medium	no	3774	3750	24
	medium	good	high biogenic	no	yes	2504	2488	16
	medium	good	high biogenic	no	no	2506	2489	17
	medium	good	high biogenic and geogenic	high	yes	47040	46611	429
	medium	good	high biogenic and geogenic	high	no	14360	14224	136
	medium	good	high biogenic and geogenic	medium	yes	5304	5250	54
	medium	good	high biogenic and geogenic	medium	no	4076	4033	43
	medium	good	high biogenic and geogenic	no	yes	2740	2709	31
	medium	good	high biogenic and geogenic	no	no	1882	1860	22
	medium	good	medium biogenic and geogenic	high	yes	5170	5143	27
	medium	good	medium biogenic and geogenic	high	no	4378	4354	24
	medium	good	medium biogenic and geogenic	medium	yes	2594	2579	15
	medium	good	medium biogenic and geogenic	medium	no	2150	2137	13
	medium	good	medium biogenic and geogenic	no	yes	1642	1632	10
	medium	good	medium biogenic and geogenic	no	no	1364	1355	9
	medium	good	medium biogenic or geogenic	high	yes	4678	4657	21
	medium	good	medium biogenic or geogenic	high	no	3908	3890	18
	medium	good	medium biogenic or geogenic	medium	yes	2580	2567	13
	medium	good	medium biogenic or geogenic	medium	no	2036	2026	10
	medium	good	medium biogenic or geogenic	no	yes	1794	1784	10
	medium	good	medium biogenic or geogenic	no	no	1530	1521	9
	medium	good	no clogging	high	yes	5272	5253	19
	medium	good	no clogging	high	no	4694	4677	17
	medium	good	no clogging	medium	yes	3080	3068	12
	medium	good	no clogging	medium	no	2504	2494	10
	medium	good	no clogging	no	yes	2118	2109	9
	medium	good	no clogging	no	no	1736	1728	8
low discharge	high	bad	high biogenic	high	yes	106728	106116	612
	high	bad	high biogenic	high	no	45736	45463	273
	high	bad	high biogenic	medium	yes	12310	12231	79
	high	bad	high biogenic	medium	no	11022	10949	73
	high	bad	high biogenic	no	yes	5194	5158	36
	high	bad	high biogenic	no	no	5216	5178	38
	high	bad	high biogenic and geogenic	high	yes	> 1,000,000		
	high	bad	high biogenic and geogenic	high	no	339320	335896	3424



low discharge	high	bad	high biogenic and geogenic	medium	yes	53712	53131	581
	high	bad	high biogenic and geogenic	medium	no	12506	12365	141
	high	bad	high biogenic and geogenic	no	yes	6820	6739	81
	high	bad	high biogenic and geogenic	no	no	4274	4221	53
	high	bad	medium biogenic and geogenic	high	yes	18756	18653	103
	high	bad	medium biogenic and geogenic	high	no	8892	8841	51
	high	bad	medium biogenic and geogenic	medium	yes	5338	5305	33
	high	bad	medium biogenic and geogenic	medium	no	4134	4108	26
	high	bad	medium biogenic and geogenic	no	yes	2504	2487	17
	high	bad	medium biogenic and geogenic	no	no	1986	1972	14
	high	bad	medium biogenic or geogenic	high	yes	19542	19451	91
	high	bad	medium biogenic or geogenic	high	no	11536	11480	56
	high	bad	medium biogenic or geogenic	medium	yes	5622	5593	29
	high	bad	medium biogenic or geogenic	medium	no	4152	4129	23
	high	bad	medium biogenic or geogenic	no	yes	3150	3132	18
	high	bad	medium biogenic or geogenic	no	no	2192	2179	13
	high	bad	no clogging	high	yes	16460	16398	62
	high	bad	no clogging	high	no	11980	11933	47
	high	bad	no clogging	medium	yes	7814	7781	33
	high	bad	no clogging	medium	no	4730	4709	21
	high	bad	no clogging	no	yes	3472	3456	16
	high	bad	no clogging	no	no	2504	2492	12
	high	good	high biogenic	high	yes	30470	30308	162
	high	good	high biogenic	high	no	17968	17869	99
	high	good	high biogenic	medium	yes	9934	9875	59
	high	good	high biogenic	medium	no	6014	5977	37
	high	good	high biogenic	no	yes	4308	4280	28
	high	good	high biogenic	no	no	3188	3167	21
	high	good	high biogenic and geogenic	high	yes	213050	211140	1910
	high	good	high biogenic and geogenic	high	no	48326	47874	452
	high	good	high biogenic and geogenic	medium	yes	11624	11508	116
	high	good	high biogenic and geogenic	medium	no	6908	6836	72
	high	good	high biogenic and geogenic	no	yes	5040	4985	55
	high	good	high biogenic and geogenic	no	no	3442	3403	39
	high	good	medium biogenic and geogenic	high	yes	9364	9317	47
	high	good	medium biogenic and geogenic	high	no	7388	7349	39
	high	good	medium biogenic and geogenic	medium	yes	4806	4779	27
	high	good	medium biogenic and geogenic	medium	no	3762	3740	22

low discharge	high	good	medium biogenic and geogenic	no	yes	3130	3111	19
	high	good	medium biogenic and geogenic	no	no	2232	2218	14
	high	good	medium biogenic or geogenic	high	yes	14072	14011	61
	high	good	medium biogenic or geogenic	high	no	7116	7084	32
	high	good	medium biogenic or geogenic	medium	yes	5098	5073	25
	high	good	medium biogenic or geogenic	medium	no	3910	3890	20
	high	good	medium biogenic or geogenic	no	yes	2782	2767	15
	high	good	medium biogenic or geogenic	no	no	2156	2144	12
	high	good	no clogging	high	yes	9686	9652	34
	high	good	no clogging	high	no	8168	8139	29
	high	good	no clogging	medium	yes	5036	5017	19
	high	good	no clogging	medium	no	3862	3847	15
	high	good	no clogging	no	yes	3298	3284	14
	high	good	no clogging	no	no	2192	2182	10
	low	bad	high biogenic	high	yes	10928	10878	50
	low	bad	high biogenic	high	no	7510	7474	36
	low	bad	high biogenic	medium	yes	4582	4559	23
	low	bad	high biogenic	medium	no	3128	3111	17
	low	bad	high biogenic	no	yes	2860	2844	16
	low	bad	high biogenic	no	no	2110	2098	12
	low	bad	high biogenic and geogenic	high	yes	13260	13157	103
	low	bad	high biogenic and geogenic	high	no	7844	7781	63
	low	bad	high biogenic and geogenic	medium	yes	4136	4100	36
	low	bad	high biogenic and geogenic	medium	no	2938	2912	26
	low	bad	high biogenic and geogenic	no	yes	2066	2046	20
	low	bad	high biogenic and geogenic	no	no	1590	1574	16
	low	bad	medium biogenic and geogenic	high	yes	4376	4357	19
	low	bad	medium biogenic and geogenic	high	no	3900	3882	18
	low	bad	medium biogenic and geogenic	medium	yes	2678	2665	13
	low	bad	medium biogenic and geogenic	medium	no	2032	2022	10
	low	bad	medium biogenic and geogenic	no	yes	1688	1679	9
	low	bad	medium biogenic and geogenic	no	no	1100	1094	6
	low	bad	medium biogenic or geogenic	high	yes	5644	5623	21
	low	bad	medium biogenic or geogenic	high	no	4464	4447	17
	low	bad	medium biogenic or geogenic	medium	yes	2770	2759	11
	low	bad	medium biogenic or geogenic	medium	no	2436	2425	11
	low	bad	medium biogenic or geogenic	no	yes	1810	1802	8
	low	bad	medium biogenic or geogenic	no	no	1610	1602	8



low discharge	low	bad	no clogging	high	yes	5740	5723	17
	low	bad	no clogging	high	no	5352	5335	17
	low	bad	no clogging	medium	yes	3374	3363	11
	low	bad	no clogging	medium	no	2770	2760	10
	low	bad	no clogging	no	yes	2516	2507	9
	low	bad	no clogging	no	no	1712	1706	6
	low	good	high biogenic	high	yes	7854	7821	33
	low	good	high biogenic	high	no	5578	5553	25
	low	good	high biogenic	medium	yes	5004	4980	24
	low	good	high biogenic	medium	no	2796	2782	14
	low	good	high biogenic	no	yes	2266	2254	12
	low	good	high biogenic	no	no	1910	1900	10
	low	good	high biogenic and geogenic	high	yes	7410	7357	53
	low	good	high biogenic and geogenic	high	no	6252	6205	47
	low	good	high biogenic and geogenic	medium	yes	3168	3143	25
	low	good	high biogenic and geogenic	medium	no	2818	2795	23
	low	good	high biogenic and geogenic	no	yes	1546	1532	14
	low	good	high biogenic and geogenic	no	no	1530	1516	14
	low	good	medium biogenic and geogenic	high	yes	4030	4014	16
	low	good	medium biogenic and geogenic	high	no	3068	3055	13
	low	good	medium biogenic and geogenic	medium	yes	2280	2270	10
	low	good	medium biogenic and geogenic	medium	no	2040	2030	10
	low	good	medium biogenic and geogenic	no	yes	1628	1620	8
	low	good	medium biogenic and geogenic	no	no	1342	1335	7
	low	good	medium biogenic or geogenic	high	yes	4736	4720	16
	low	good	medium biogenic or geogenic	high	no	3816	3802	14
	low	good	medium biogenic or geogenic	medium	yes	2554	2544	10
	low	good	medium biogenic or geogenic	medium	no	2154	2145	9
	low	good	medium biogenic or geogenic	no	yes	1568	1561	7
	low	good	medium biogenic or geogenic	no	no	1570	1563	7
	low	good	no clogging	high	yes	5632	5616	16
	low	good	no clogging	high	no	3752	3741	11
	low	good	no clogging	medium	yes	2880	2871	9
	low	good	no clogging	medium	no	2420	2412	8
	low	good	no clogging	no	yes	2090	2083	7
	low	good	no clogging	no	no	1588	1582	6
	medium	bad	high biogenic	high	yes	15496	15421	75
	medium	bad	high biogenic	high	no	9762	9713	49

low discharge	medium	bad	high biogenic	medium	yes	5958	5926	32
	medium	bad	high biogenic	medium	no	4058	4035	23
	medium	bad	high biogenic	no	yes	3766	3744	22
	medium	bad	high biogenic	no	no	2506	2491	15
	medium	bad	high biogenic and geogenic	high	yes	37648	37341	307
	medium	bad	high biogenic and geogenic	high	no	11710	11610	100
	medium	bad	high biogenic and geogenic	medium	yes	5580	5529	51
	medium	bad	high biogenic and geogenic	medium	no	5002	4955	47
	medium	bad	high biogenic and geogenic	no	yes	2680	2653	27
	medium	bad	high biogenic and geogenic	no	no	1720	1702	18
	medium	bad	medium biogenic and geogenic	high	yes	6158	6130	28
	medium	bad	medium biogenic and geogenic	high	no	4816	4793	23
	medium	bad	medium biogenic and geogenic	medium	yes	3208	3192	16
	medium	bad	medium biogenic and geogenic	medium	no	2510	2497	13
	medium	bad	medium biogenic and geogenic	no	yes	1890	1879	11
	medium	bad	medium biogenic and geogenic	no	no	1524	1515	9
	medium	bad	medium biogenic or geogenic	high	yes	5622	5600	22
	medium	bad	medium biogenic or geogenic	high	no	4788	4768	20
	medium	bad	medium biogenic or geogenic	medium	yes	3450	3435	15
	medium	bad	medium biogenic or geogenic	medium	no	2826	2813	13
	medium	bad	medium biogenic or geogenic	no	yes	1880	1871	9
	medium	bad	medium biogenic or geogenic	no	no	1668	1660	8
	medium	bad	no clogging	high	yes	7540	7516	24
	medium	bad	no clogging	high	no	5512	5494	18
	medium	bad	no clogging	medium	yes	3554	3542	12
	medium	bad	no clogging	medium	no	2884	2873	11
	medium	bad	no clogging	no	yes	2384	2375	9
	medium	bad	no clogging	no	no	1970	1962	8
	medium	good	high biogenic	high	yes	9284	9243	41
	medium	good	high biogenic	high	no	7522	7487	35
	medium	good	high biogenic	medium	yes	4216	4195	21
	medium	good	high biogenic	medium	no	3626	3607	19
	medium	good	high biogenic	no	yes	2606	2592	14
	medium	good	high biogenic	no	no	2506	2492	14
	medium	good	high biogenic and geogenic	high	yes	18816	18674	142
	medium	good	high biogenic and geogenic	high	no	7988	7925	63
	medium	good	high biogenic and geogenic	medium	yes	3668	3637	31
	medium	good	high biogenic and geogenic	medium	no	3170	3142	28



low discharge	medium	good	high biogenic and geogenic	no	yes	1990	1972	18
	medium	good	high biogenic and geogenic	no	no	1804	1787	17
	medium	good	medium biogenic and geogenic	high	yes	5228	5206	22
	medium	good	medium biogenic and geogenic	high	no	4378	4359	19
	medium	good	medium biogenic and geogenic	medium	yes	2668	2655	13
	medium	good	medium biogenic and geogenic	medium	no	2086	2076	10
	medium	good	medium biogenic and geogenic	no	yes	1616	1608	8
	medium	good	medium biogenic and geogenic	no	no	1334	1327	7
	medium	good	medium biogenic or geogenic	high	yes	4794	4777	17
	medium	good	medium biogenic or geogenic	high	no	4294	4278	16
	medium	good	medium biogenic or geogenic	medium	yes	3130	3117	13
	medium	good	medium biogenic or geogenic	medium	no	2530	2519	11
	medium	good	medium biogenic or geogenic	no	yes	2018	2009	9
	medium	good	medium biogenic or geogenic	no	no	1570	1563	7
	medium	good	no clogging	high	yes	5746	5729	17
	medium	good	no clogging	high	no	4370	4357	13
	medium	good	no clogging	medium	yes	3606	3594	12
	medium	good	no clogging	medium	no	2458	2450	8
	medium	good	no clogging	no	yes	2358	2350	8
	medium	good	no clogging	no	no	1920	1913	7
no damming	high	bad	high biogenic	high	yes	23490	23355	135
	high	bad	high biogenic	high	no	11770	11700	70
	high	bad	high biogenic	medium	yes	6720	6677	43
	high	bad	high biogenic	medium	no	5080	5046	34
	high	bad	high biogenic	no	yes	3792	3765	27
	high	bad	high biogenic	no	no	2476	2458	18
	high	bad	high biogenic and geogenic	high	yes	95022	94102	920
	high	bad	high biogenic and geogenic	high	no	25162	24908	254
	high	bad	high biogenic and geogenic	medium	yes	7406	7326	80
	high	bad	high biogenic and geogenic	medium	no	5786	5721	65
	high	bad	high biogenic and geogenic	no	yes	3082	3045	37
	high	bad	high biogenic and geogenic	no	no	2066	2041	25
	high	bad	medium biogenic and geogenic	high	yes	6658	6622	36
	high	bad	medium biogenic and geogenic	high	no	5664	5632	32
	high	bad	medium biogenic and geogenic	medium	yes	2494	2479	15
	high	bad	medium biogenic and geogenic	medium	no	2544	2528	16
	high	bad	medium biogenic and geogenic	no	yes	2038	2024	14
	high	bad	medium biogenic and geogenic	no	no	1464	1454	10

no damming	high	bad	medium biogenic or geogenic	high	yes	7608	7572	36
	high	bad	medium biogenic or geogenic	high	no	4200	4180	20
	high	bad	medium biogenic or geogenic	medium	yes	3140	3124	16
	high	bad	medium biogenic or geogenic	medium	no	2464	2451	13
	high	bad	medium biogenic or geogenic	no	yes	2124	2112	12
	high	bad	medium biogenic or geogenic	no	no	1612	1602	10
	high	bad	no clogging	high	yes	6160	6137	23
	high	bad	no clogging	high	no	5176	5156	20
	high	bad	no clogging	medium	yes	5002	4981	21
	high	bad	no clogging	medium	no	3082	3069	13
	high	bad	no clogging	no	yes	2352	2341	11
	high	bad	no clogging	no	no	1826	1817	9
	high	good	high biogenic	high	yes	13594	13522	72
	high	good	high biogenic	high	no	7368	7327	41
	high	good	high biogenic	medium	yes	4278	4253	25
	high	good	high biogenic	medium	no	3562	3540	22
	high	good	high biogenic	no	yes	2500	2484	16
	high	good	high biogenic	no	no	2506	2489	17
	high	good	high biogenic and geogenic	high	yes	25322	25095	227
	high	good	high biogenic and geogenic	high	no	12508	12391	117
	high	good	high biogenic and geogenic	medium	yes	4176	4134	42
	high	good	high biogenic and geogenic	medium	no	3098	3066	32
	high	good	high biogenic and geogenic	no	yes	2370	2344	26
	high	good	high biogenic and geogenic	no	no	1754	1734	20
	high	good	medium biogenic and geogenic	high	yes	5358	5331	27
	high	good	medium biogenic and geogenic	high	no	3642	3623	19
	high	good	medium biogenic and geogenic	medium	yes	2502	2488	14
	high	good	medium biogenic and geogenic	medium	no	2212	2199	13
	high	good	medium biogenic and geogenic	no	yes	1632	1622	10
	high	good	medium biogenic and geogenic	no	no	1330	1321	9
	high	good	medium biogenic or geogenic	high	yes	5150	5128	22
	high	good	medium biogenic or geogenic	high	no	4060	4042	18
	high	good	medium biogenic or geogenic	medium	yes	2860	2846	14
	high	good	medium biogenic or geogenic	medium	no	2408	2396	12
	high	good	medium biogenic or geogenic	no	yes	1854	1844	10
	high	good	medium biogenic or geogenic	no	no	1522	1514	8
	high	good	no clogging	high	yes	6428	6406	22
	high	good	no clogging	high	no	4514	4498	16



no damming	high	good	no clogging	medium	yes	3198	3186	12
	high	good	no clogging	medium	no	2616	2606	10
	high	good	no clogging	no	yes	2028	2019	9
	high	good	no clogging	no	no	1664	1657	7
	low	bad	high biogenic	high	yes	5100	5077	23
	low	bad	high biogenic	high	no	3900	3881	19
	low	bad	high biogenic	medium	yes	2566	2553	13
	low	bad	high biogenic	medium	no	2316	2304	12
	low	bad	high biogenic	no	yes	1886	1876	10
	low	bad	high biogenic	no	no	1330	1322	8
	low	bad	high biogenic and geogenic	high	yes	5626	5582	44
	low	bad	high biogenic and geogenic	high	no	3754	3724	30
	low	bad	high biogenic and geogenic	medium	yes	2160	2141	19
	low	bad	high biogenic and geogenic	medium	no	1804	1788	16
	low	bad	high biogenic and geogenic	no	yes	1262	1250	12
	low	bad	high biogenic and geogenic	no	no	944	935	9
	low	bad	medium biogenic and geogenic	high	yes	2974	2961	13
	low	bad	medium biogenic and geogenic	high	no	2192	2182	10
	low	bad	medium biogenic and geogenic	medium	yes	1882	1873	9
	low	bad	medium biogenic and geogenic	medium	no	1492	1484	8
	low	bad	medium biogenic and geogenic	no	yes	1182	1176	6
	low	bad	medium biogenic and geogenic	no	no	1052	1046	6
	low	bad	medium biogenic or geogenic	high	yes	3550	3537	13
	low	bad	medium biogenic or geogenic	high	no	2718	2707	11
	low	bad	medium biogenic or geogenic	medium	yes	1876	1868	8
	low	bad	medium biogenic or geogenic	medium	no	1562	1555	7
	low	bad	medium biogenic or geogenic	no	yes	1256	1250	6
	low	bad	medium biogenic or geogenic	no	no	944	940	4
	low	bad	no clogging	high	yes	3622	3611	11
	low	bad	no clogging	high	no	3450	3439	11
	low	bad	no clogging	medium	yes	2506	2498	8
	low	bad	no clogging	medium	no	2116	2109	7
	low	bad	no clogging	no	yes	1362	1357	5
	low	bad	no clogging	no	no	1176	1172	4
	low	good	high biogenic	high	yes	4552	4533	19
	low	good	high biogenic	high	no	3342	3327	15
	low	good	high biogenic	medium	yes	2476	2464	12
	low	good	high biogenic	medium	no	1854	1845	9

no damming	low	good	high biogenic	no	yes	1540	1532	8
	low	good	high biogenic	no	no	1100	1094	6
	low	good	high biogenic and geogenic	high	yes	4066	4037	29
	low	good	high biogenic and geogenic	high	no	2858	2837	21
	low	good	high biogenic and geogenic	medium	yes	1800	1786	14
	low	good	high biogenic and geogenic	medium	no	1608	1595	13
	low	good	high biogenic and geogenic	no	yes	1154	1144	10
	low	good	high biogenic and geogenic	no	no	892	884	8
	low	good	medium biogenic and geogenic	high	yes	2706	2695	11
	low	good	medium biogenic and geogenic	high	no	2190	2181	9
	low	good	medium biogenic and geogenic	medium	yes	1622	1615	7
	low	good	medium biogenic and geogenic	medium	no	1240	1234	6
	low	good	medium biogenic and geogenic	no	yes	1140	1134	6
	low	good	medium biogenic and geogenic	no	no	852	848	4
	low	good	medium biogenic or geogenic	high	yes	2814	2804	10
	low	good	medium biogenic or geogenic	high	no	2412	2403	9
	low	good	medium biogenic or geogenic	medium	yes	1764	1757	7
	low	good	medium biogenic or geogenic	medium	no	1348	1343	5
	low	good	medium biogenic or geogenic	no	yes	1166	1161	5
	low	good	medium biogenic or geogenic	no	no	1006	1002	4
	low	good	no clogging	high	yes	3328	3319	9
	low	good	no clogging	high	no	3024	3015	9
	low	good	no clogging	medium	yes	2212	2205	7
	low	good	no clogging	medium	no	1566	1561	5
	low	good	no clogging	no	yes	1376	1371	5
	low	good	no clogging	no	no	1174	1170	4
	medium	bad	high biogenic	high	yes	7842	7804	38
	medium	bad	high biogenic	high	no	5072	5047	25
	medium	bad	high biogenic	medium	yes	3090	3073	17
	medium	bad	high biogenic	medium	no	2662	2647	15
	medium	bad	high biogenic	no	yes	2054	2042	12
	medium	bad	high biogenic	no	no	1746	1735	11
	medium	bad	high biogenic and geogenic	high	yes	7260	7201	59
	medium	bad	high biogenic and geogenic	high	no	4686	4646	40
	medium	bad	high biogenic and geogenic	medium	yes	2782	2757	25
	medium	bad	high biogenic and geogenic	medium	no	2018	1999	19
	medium	bad	high biogenic and geogenic	no	yes	1430	1416	14
	medium	bad	high biogenic and geogenic	no	no	1208	1195	13



no damming	medium	bad	medium biogenic and geogenic	high	yes	3206	3191	15
	medium	bad	medium biogenic and geogenic	high	no	2820	2806	14
	medium	bad	medium biogenic and geogenic	medium	yes	2116	2105	11
	medium	bad	medium biogenic and geogenic	medium	no	1764	1755	9
	medium	bad	medium biogenic and geogenic	no	yes	1338	1330	8
	medium	bad	medium biogenic and geogenic	no	no	1114	1107	7
	medium	bad	medium biogenic or geogenic	high	yes	3708	3693	15
	medium	bad	medium biogenic or geogenic	high	no	3052	3040	12
	medium	bad	medium biogenic or geogenic	medium	yes	2236	2226	10
	medium	bad	medium biogenic or geogenic	medium	no	1902	1893	9
	medium	bad	medium biogenic or geogenic	no	yes	1236	1230	6
	medium	bad	medium biogenic or geogenic	no	no	1176	1170	6
	medium	bad	no clogging	high	yes	4284	4271	13
	medium	bad	no clogging	high	no	3874	3861	13
	medium	bad	no clogging	medium	yes	2364	2356	8
	medium	bad	no clogging	medium	no	2272	2264	8
	medium	bad	no clogging	no	yes	1624	1618	6
	medium	bad	no clogging	no	no	1352	1347	5
	medium	good	high biogenic	high	yes	4980	4958	22
	medium	good	high biogenic	high	no	4192	4173	19
	medium	good	high biogenic	medium	yes	3168	3152	16
	medium	good	high biogenic	medium	no	2216	2205	11
	medium	good	high biogenic	no	yes	1784	1774	10
	medium	good	high biogenic	no	no	1570	1561	9
	medium	good	high biogenic and geogenic	high	yes	4376	4343	33
	medium	good	high biogenic and geogenic	high	no	3454	3427	27
	medium	good	high biogenic and geogenic	medium	yes	2312	2293	19
	medium	good	high biogenic and geogenic	medium	no	1642	1628	14
	medium	good	high biogenic and geogenic	no	yes	1374	1361	13
	medium	good	high biogenic and geogenic	no	no	1078	1068	10
	medium	good	medium biogen and geogen	high	yes	3078	3065	13
	medium	good	medium biogen and geogen	high	no	2338	2328	10
	medium	good	medium biogen and geogen	medium	yes	1700	1692	8
	medium	good	medium biogen and geogen	medium	no	1392	1385	7
	medium	good	medium biogen and geogen	no	yes	1134	1128	6
	medium	good	medium biogen and geogen	no	no	904	899	5
	medium	good	medium biogen or geogen	high	yes	3598	3585	13
	medium	good	medium biogen or geogen	high	no	2836	2825	11

no damming	medium	good	medium biogen or geogen	medium	yes	1948	1940	8
	medium	good	medium biogen or geogen	medium	no	1544	1537	7
	medium	good	medium biogen or geogen	no	yes	1320	1314	6
	medium	good	medium biogen or geogen	no	no	1114	1109	5
	medium	good	no clogging	high	yes	3782	3771	11
	medium	good	no clogging	high	no	3150	3140	10
	medium	good	no clogging	medium	yes	2352	2344	8
	medium	good	no clogging	medium	no	1804	1798	6
	medium	good	no clogging	no	yes	1404	1399	5
	medium	good	no clogging	no	no	1276	1271	5



S 5: CORINE land cover data (European Environment Agency, 2019). Classification of the land cover types in the major groups "Agricultural Areas" and "Forests" and "Semi-Natural Areas".

ID	Major group	Land cover type
	Agricultural Areas	
12		Non-irrigated arable land
13		Permanently irrigated land
14		Rice fields
15		Vineyards
16		Fruit trees and berry plantations
17		Olive groves
18		Pastures
19		Annual crops associated with permanent crops
20		Complex cultivation patterns
21		Land principally occupied by agriculture, with significant areas of natural vegetation
22		Agro-forestry areas
	Forests and Semi-Natural Areas	
23		Broad-leaved forest
24		Coniferous forest
25		Mixed forest
26		Natural grasslands
27		Moors and heathland
28		Sclerophyllous vegetation
29		Transitional woodland-shrub
30		Beaches, dunes and sands
31		Bare rocks
32		Sparsely vegetated areas
33		Burnt areas
34		Glaciers and perpetual snow

