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Ecological status assessment of the rivers in Slovenia – an overview

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Abstract. Adoption of the Water Framework Directive (Directive 2000/60/EC) includes ecological assessment of water bodies with biological communities. A WFD compliant ecological assessment includes ecological typology of water bodies, definition of reference conditions and classification system with five ecological classes. In this paper, an overview is given on the development of the ecological assessment system for Slovenian rivers. A special emphasis is laid on ecological river typology. 74 ecological river types were defined using bioregions or large rivers, and nine natural environmental descriptors recognised in literature as being important for river community composition in Slovenia. The rivers' ecological status is assessed based on two biological elements, phytobenthos and macrophytes, and on benthic invertebrates, whereas an assessment system for fish is still under development. Phytoplankton rarely occurs in Slovenian rivers; therefore phytoplankton-based assessment systems were not developed. The Slovenian river classification system consists of three modules with pressure-specific assessment methods. The impact of three groups of pressures is assessed: organic pollution (saprobity), nutrient load (eutrophication) and hydromorphological alterations/general degradation. Phytobenthos and macrophytes are used to assess river saprobic and trophic status, whereas benthic invertebrates are used to assess saprobity and impact of hydromorphological alteration/general degradation. In our study, the impact of hydromorphological alterations of the Drava River was assessed using benthic invertebrates. A Slovenian multimetric index SMEIH was calculated at fifteen sampling sites. Good to bad ecological status was assessed. Moreover, at most sites within the Heavily Modified Water Bodies of the Drava River, good ecological potential was not achieved. In conclusion, mitigation measures are needed on the Drava River in order to achieve objectives of the Water Framework Directive.

Key words: WFD, ecological status, benthic invertebrates, hydromorphology, heavily modified water bodies, ecological potential, Drava River

Izvleček. VREDNOTENJE EKOLOŠKEGA STANJA REK V SLOVENIJI – PREGLED – Sprejetje Vodne direktive (Direktiva 2000/60/ES) vključuje tudi ekološko vrednotenje stanja vodnih teles z združbami vodnih organizmov. Vrednotenje v skladu z vodno direktivo vključuje ekološko tipologijo vodnih teles, določitev referenčnih razmer in razvrščanje v pet razredov ekološkega stanja. V tem članku je podan pregled razvoja metodologij vrednotenja ekološkega stanja za reke v Sloveniji. Poseben poudarek je dan ekološki tipologiji rek. 74 ekoloških tipov rek je bilo določenih z uporabo bioregij oz. velikih rek in devet naravnih deskriptorjev, ki so bili v literaturi prepoznani kot pomembni za združbe vodnih organizmov v Sloveniji. Ekološko stanje voda vrednotimo z uporabo dveh bioloških elementov fitobentosa in makrofitov ter bentoških nevretenčarjev, medtem ko sistem na podlagi rib še razvijamo. Fitoplankton se v rekah v Sloveniji redko pojavlja, zato sistemi vrednotenja na podlagi fitoplanktona niso bili razviti. Slovenski sistem razvrščanja sestavljajo trije moduli sistemi vrednotenja, občutljivimi za stres. Vrednotimo vpliv treh skupin obremenitev: obremenitve z organskimi snovmi (saprobnost), obremenitve s hranili (trofičnost) in vpliv hidromorfološke spremenjenosti/splošne degradiranosti. Vpliv hidromorfološke spremenjenosti reke Drave smo ovrednotili z bentoškimi nevretenčarji. Slovenski multimetrijski indeks SMEIH je bil izračunan na 15 mestih vzorčenja. Ugotovili smo dobro do zelo slabo stanje. Za večino mest vzorčenja močno preoblikovanih vodnih teles reke Drave smo ugotovili, da ne dosegajo dobrega ekološkega potenciala. Na reki Dravi je treba izpeljati omilitvene ukrepe, če želimo doseči okoljske cilje vodne direktive.

Ključne besede: Vodna direktiva, ekološko stanje, bentoški nevretenčarji, hidromorfologija, močno preoblikovana vodna telesa, ekološki potencial, reka Drava

Introduction

Adoption of the European Water Framework Directive (WFD) (Directive 2000/60/EC) changed water management in EU member countries. Changes are reflected in the assessment of the ecological status of water bodies. Ecological quality (status) of surface waters is measured using a range of biological communities rather than the more limited aspects of the chemical quality (Moss 2007). Actually, biological communities are showing a response to all major aquatic components water quality, water quantity and habitat quality. Most biological assessment systems are based on the concept of comparing the current biological community to the »reference conditions« - a status of community observed in the absence of human disturbance or alteration (Bailey et al. 2004). Although reference conditions approach is widely used in ecological assessment, no general consensus exists regarding how pristine a reference condition should characterise (see Hawkins et al. 2000 for a review). In the WFD implementation process, guidance was prepared in order to use conditions with comparable degree of changes across Europe (Wallin et al. 2003). According to the WFD, ecological status assessment has to be type-specific. Biological communities and reference conditions differ across streams due to physical and morphological attributes, such as stream size, altitude, catchment geology. A stream typology classifies streams or stream reaches into entities with a limited variability of both community composition and abiotic factors (Lorenz et al. 2004). In the WFD typology, a top-down approach is defined by using geomorphological characteristics of river landscapes and individual streams. As a framework for national stream typologies, WFD includes 25 European ecoregions defined by Illies (1978), which should be upgraded by several descriptors of the system A or system B. Some water bodies were altered in the past to suit a specific purpose (e.g. hydroelectric power plants, flood protection, navigation). When their original appearance is significantly changed, water bodies can be defined as heavily modified water bodies (HMWBs). Instead of reference conditions, maximum ecological potential is defined and ecological potential is assessed.

The objective of this paper is to give an overview of the ecological assessment system development for rivers in Slovenia. A special attention is given to the ecological typology of our rivers and ecological assessment of the Drava River.

Ecological typology of Slovenian rivers

The ecological river typology in Slovenia was developed according to the System B of the WFD Annex II, which allows any natural environmental parameter influencing communities to be included. In the first step, a re-delineation of European ecoregions defined by Illies (1978) was performed (Urbanič 2008a). In total, Slovenia shares four European ecoregions: Italy, Corsica, Malta (Ecoregion 3), The Alps (Ecoregion 4), Dinaric western Balkans (Ecoregion 5) and Hungarian Plains (Pannonian Lowland) (Ecoregion 11). However, Urbanič (2008a) changed the criteria for delineation of the Ecoregion 3 in the north-east and named it Po Lowland. In the second step, ecoregions were further subdivided into bioregions and special »large river« units (Urbanič 2008b, 2009). Bioregions were defined using a synthesis of abiotic top-down approach (altitude of the catchment area, geology and division between the Danube and Adriatic river basins) and community based bottom-up approach. Sixteen bioregions were defined, but one bioregion has no rivers with a catchment area >10 km^2. Large rivers were defined as rivers with a catchment area >2,500 km^2 and/or mean discharge in a period (sQs) >50m^3/s and were further divided. Based on ecoregion, maximum water temperature and geomorphologic type, ten large river types were defined. Additional 64 river types were defined using bioregion and nine environmental parameters as river type descriptors. Selection of descriptors was based on literature data with information on the influence of environmental variables on aquatic communities, with special emphasis on information from Slovenia (Urbanič 2004, Urbanič & Toman 2007). Size class, karst spring influence, intermittent karst spring influence, limnocrene spring influence, lake outflow influence, intermittency, periodical flooding, meandering and altitude class were selected. Some parameters (e.g. size class) were used as descriptors of all river types, whereas others were used in just certain bioregions. Besides large rivers, three river size classes were defined using catchment size classes or combination of catchment size class and mean discharge in a period (sQs):

- Small rivers (10-100 km^2)
- Medium-sized rivers (>100-1000 km^2)
- Medium-sized to large rivers (>1000-2500 km^2 and sQs < 50m^3/s)

Most other descriptors were used based on presence/absence of information, whereas in the Alps the altitudinal class >700 m a.s.l. was used where no karst spring influence was detected. Altogether, 74 river types were defined with a length of at least 5 km (App. 1). Relatively high number of ecological river types is a result of the ecological variety of the area. In the territory of Slovenia, four different geographic regions meet the Pannonian lowland, Alps, Dinarides and Mediterranean (Perko and Orožen-Adamič 1998), four ecoregions (Urbanič 2008a), two main river basins that influence fish communities (Urbanič 2008b), big karst area with karst phenomena (Gams 2004), variety of geologies and rivers of varied sizes. Hering et al. (2010) wrote that typology is always a trade-off between having all environmental factors included and having a manageable typology. Therefore broadly or strictly defined river types might be developed across Europe, but no compilation was made. It was also found that parameters relevant for typology are among the major sources of uncertainty in ecological assessment (Hering et al. 2010). In our opinion, this is very much true with broad types where broad reference conditions are defined (see Hawkins et al. 2000). Therefore, it is probably better to strictly define river types and merge them when necessary to get relevant community specific units for development of the assessment system than to define broad types with high variability in reference conditions of some biological elements. Biological community specific typologies are used for ecological assessment system development; e.g. in Slovenia benthic invertebrate based ecological river types were merged to define type specific reference values using macrophytes (Kuhar et al. 2011).

Ecological assessment and classification of Slovenian rivers

Only three of the four biological elements listed in the WFD are relevant for ecological assessment of Slovenian rivers. Phytoplankton is not relevant as it occurs only occasionally in some rivers. So far, assessment systems were developed based on phytobenthos and macrophytes and benthic invertebrates, whereas fish-based assessment systems are still under development (UL 2009). A stressor-specific approach was used for ecological assessment system development in Slovenia. Three main stressors occur in Slovenia: eutrophication, organic pollution and hydromorphological alterations/general degradation (Fig. 1). BQE stressor-specific assessment systems were developed based on suitability to detect specific stress type (e.g. Hering et al. 2006) and biomonitoring tradition. Phytobenthos and macrophyte-based assessment system consists of eutrophication and saprobity (organic pollution) modules, whereas benthic invertebrate-based assessment system is composed of hydromorphological alterations/general degradation and saprobity modules. Final ecological assessment of the water body is made with a combination of individual BQE classification results using »one-out all-out principle«; the lowest score off all assessment results determines the overall ecological quality class (see WFD, Annex V, section 1.4.2 (i)). This principle is in line with the precautionary principle, and will provide sufficient protection for the most vulnerable BQE (Hering et al. 2010).

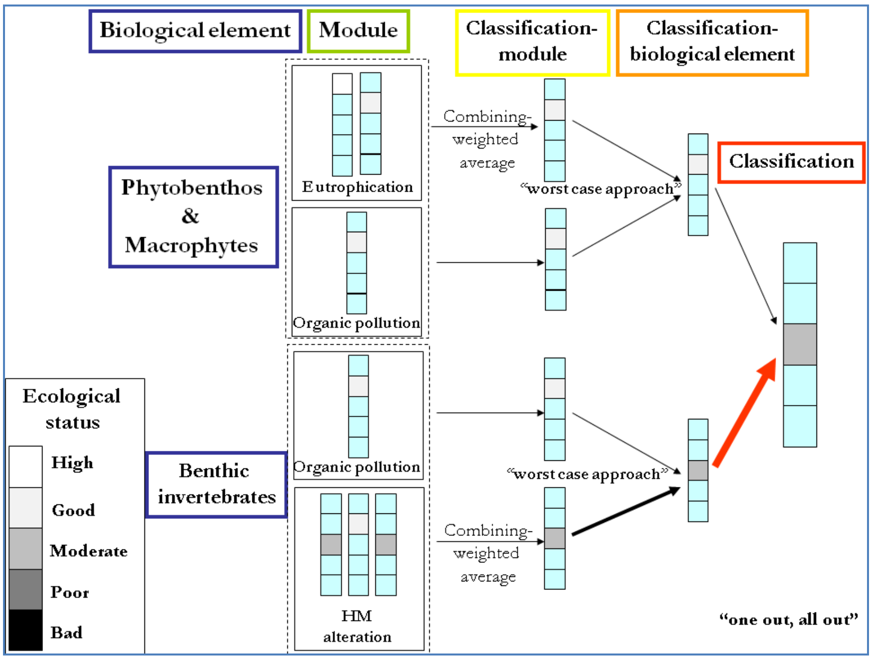

Figure 1. Biological quality element (BQE)-based classification of Slovenian rivers.
Slika 1. Razvrščanje rek v Sloveniji z biološkimi elementi kakovosti.

Heavily modified water bodies

Heavily modified water bodies (HMWBs) are a special category of altered natural surface water bodies as the result of hydromorphological pressures. The main environmental objectives are good chemical status and good ecological potential. The latter is defined as the ecological quality expected under the conditions of the implementation of all possible mitigation measures. Based on the Prague approach, which is mainly based on measures (Kampa & Kranz 2005), 22 HMWB candidates were defined in Slovenia, 20 of them on rivers (UL 2005). Urbanič et al. (2010) applied the Common Implementation Strategy guidance approach by using biological assessment and concluded that only 17 of 20 HMWBs candidates should be categorised as HMWBs. According to the Slovenian classification system, there is no difference between good ecological status (GES) and good ecological potential (GEP) values in saprobity and eutrophication modules. Main difference can be found in the hydromorphological alteration/general degradation module, where lower objectives were set for GEP. Boundary value between good and moderate ecological potential equals a boundary value between moderate and poor ecological status (Fig. 2). However, all other boundary values of ecological potential classes have not been defined yet.

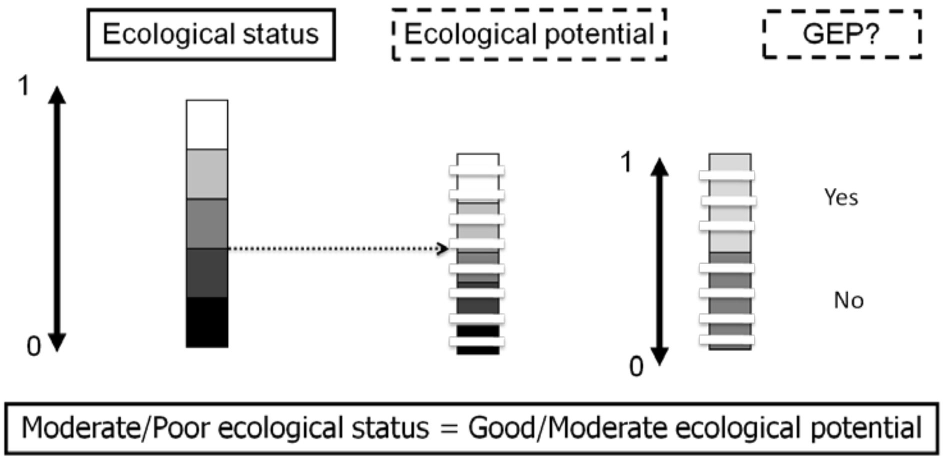

Figure 2. Relationship between ecological status and good ecological potential (GEP) in the hydromorphological alteration/general degradation module (modified after Urbanič et al. 2010).
Slika 2. Povezanost ekološkega stanja in dobrega ekološkega potenciala (DEP) v modulu hidromorfološka spremenjenost/splošna degradiranost (spremenjeno po Urbanič et al. 2010).

The Drava river – case study

Seven HMWB candidates were defined on the Drava River in Slovenia (UL 2005), with which two artificial water bodies are also connected. In order to assess ecological status of the Drava River, fifteen sampling sites were selected (Fig. 3). Benthic invertebrates were sampled in winter at low water flow using Slovenian multi-microhabitat type sampling approach applied for river bioassessment in Slovenia (UL 2009). At each sampling site, twenty sub-sampling units with a total sampling area of 1.25 m^2 were selected in proportion to the coverage of microhabitat types. In the laboratory, sub-sampling was performed in order to obtain benthic invertebrates from a quarter of the whole field sample (Petkovska & Urbanič 2009). Benthic invertebrates were determined to the taxonomic level used for the assessment of ecological river status in Slovenia (UL 2009), i.e. mostly to the species or genus. Ecological status according to the hydromorphological alteration/general degradation module was defined using Slovenian multimetric index $SMEIH_{VR}$ (Urbanič 2009):

$$SMEIH_{\mathrm{VR_i}} = \frac{2 * \mathrm{RFI}_{VR_i} + \%ALP(100\%)}{3} \quad \text{... (1)}$$

where RFI_{VR} is River Fauna Index of large rivers and %ALP (100%) is percentage of akal, lithal and psammal preferences (sum 100%). First metric was calculated according to indicative values defined in Urbanič (2009), whereas calculation programme Asterix 3.01 (Aqem consortium 2002) was used for calculation of the latter metric. Good to bad status sites were found on the Drava River (Fig. 3). However, at all water bodies of the »old« Drava River downstream of Maribor, most samples were classified as good or moderate. Therefore, only four of seven HMWB candidates were recognised as appropriate HMWB candidates (Urbanič et al. 2010). Sites at those four HMWB were classified according to the classification rules for ecological potential (Fig. 2). Only two sites close to the confluence of the Drava and Meža Rivers were classified as achieving GEP, but not other (Fig. 4). Locally, the Meža has a positive influence on the benthic invertebrate community of the Drava River, but not further downstream. It is evident that inflow streams and rivers can locally improve ecological potential, but due to additional alterations the effect is soon diminished. Nevertheless, Urbanič et al. (2010) found that none of the four HMWB of the Drava River achieves GEP at the water body level. Therefore mitigation measures are needed to achieve the WFD objectives.

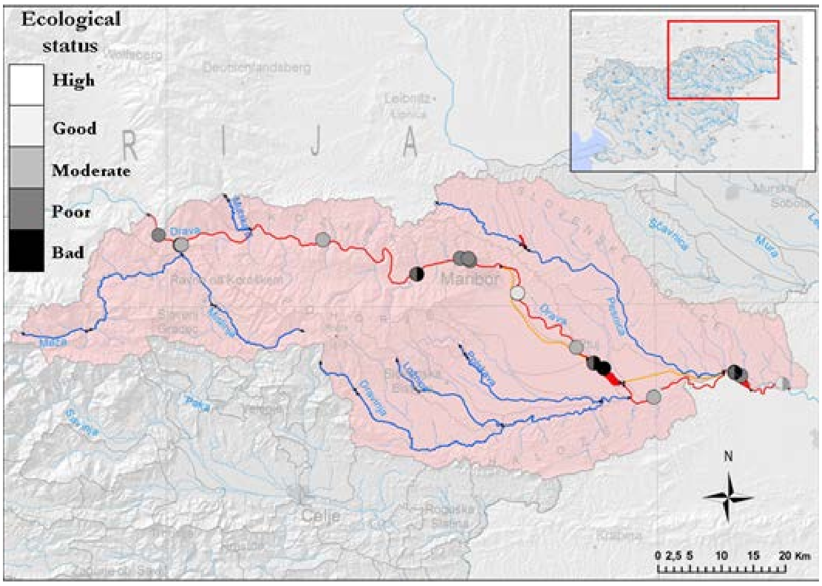

Figure 3. Sampling sites of the Drava River with assessed ecological status according to the hydromorphological alteration/general degradation module.
Slika 3. Vzorčna mesta na reki Dravi z ocenjenim ekološkim stanjem po modulu hidromorfološka spremenjenost/splošna degradiranost.

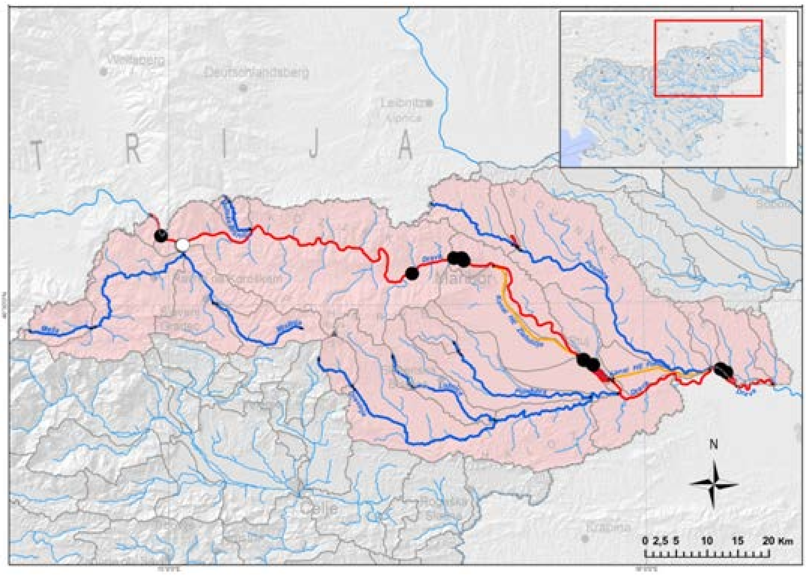

Figure 4. Sampling sites of the Drava River with assessed ecological potential;
○ - good ecological potential is achieved, ● – good ecological potential is not achieved.
Slika 4. Vzorčna mesta na reki Dravi z ocenjenim ekološkim potencialom;
○ – dober ekološki potencial je dosežen, ● – dober ekološki potencial ni dosežen.

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I would like to thank colleagues who helped to determine benthic invertebrates, and Maja Kregar for cartography. The paper was prepared based on the lecture given at the International Conference on the Drava River in 2010 at Dravograd.

Povzetek

Sprejetje Vodne direktive (Direktiva 2000/60/ES) je v državah članicah Evropske unije vplivalo na upravljanje voda. Spremembe se odražajo tudi na vrednotenju ekološkega stanja vodnih teles. V prispevku podajamo pregled razvoja metodologij vrednotenja ekološkega stanja za reke v Sloveniji s poudarkom na določitvi ekoloških tipov rek in vrednotenju ekološkega stanja z biološkimi elementi. Izhodišče vrednotenja ekološkega stanja so za tip vodnega telesa značilne referenčne razmere. Določitev ekoloških tipov smo opravili v skladu s sistemom B aneksa II Vodne direktive. Poleg deskriptorja bioregija oz. velika reka smo za opis tipov uporabili še devet naravnih deskriptorjev, ki so bili v literaturi prepoznani kot pomembni za združbe vodnih organizmov v Sloveniji. Določili smo 74 ekoloških tipov rek Slovenije daljših od 5 km. Ekološko stanje rek v skladu z Vodno direktivo vrednotimo s štirimi biološkimi elementi. V Sloveniji smo razvili metode vrednotenja ekološkega stanja za biološka elementa fitobentos in makrofiti ter bentoški nevretenčarji. Fitoplankton v rekah v Sloveniji ni relevanten biološki element, medtem ko metode vrednotenja ekološkega stanja rek z ribami še razvijamo. Značilnost vseh razvitih metod vrednotenja ekološkega stanja je, da so za obremenitev značilne. Vsaka metoda vrednotenja in razvrščanja vodnih teles naslavlja vpliv ene od treh najpomembnejših obremenitev; obremenitev z organskimi snovmi (saprobnost), obremenitev s hranili (trofičnost) in hidromorfološko spremenjenost/splošno degradiranost. Končna ocena vodnega telesa in uvrstitev v enega od pet razredov ekološkega stanja je določena z uporabo pravila »najslabše določi«. Vseh vodnih teles ne razvrščamo v razrede ekološkega stanja. Umetna in močno preoblikovana vodna telesa (MPVT) uvrščamo v razrede ekološkega potenciala. Za MPVT uporabljamo manj stroge kriterije kot za primerljiva naravna vodna telesa, vendar le glede na vpliv hidromorfoloških obremenitev. Za preverjanje doseganja okoljskih ciljev MPVT po Vodni direktivi smo mejno vrednost za dober/zmerni ekološki potencial izenačili z mejno vrednostjo zmerno/slabo ekološko stanje. Ovrednotenje reke Drave po modulu hidromorfološka spremenjenost/splošna degradiranost smo opravili na podlagi bentoških nevretenčarjev z indeksom SMEIH za velike reke. Ugotovili smo, da na odseku reke Drave v Sloveniji najdemo mesta z dobrim do zelo slabim stanjem. Večina mest na »stari« Dravi smo uvrstili v razred dobro ali zmerno stanje, medtem ko so taka mesta na odseku reke Drave med Dravogradom in Mariborom redka. Večina preverjenih mest gorvodno od Maribora ni dosegla dobrega ekološkega potenciala, ki je eden od okoljskih ciljev za MPVT. Metode vrednotenja ekološkega stanja se bodo v prihodosti še dopolnile, predvsem z biološkimi elementi, na podlagi katerih še nimamo razvitih metod vrednotenja.

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Appendix 1. List of ecological types of rivers in Slovenia.

Eco-region	Type no.	River type name
3	1	Small rivers/Lower Vipava valley and Brda hills
	2	Medium-sized rivers/Lower Vipava valley and Brda hills
4	3	Small rivers/Carbonate Alps of the Danube river basin
	4	Small mountainous rivers/Carbonate Alps of the Danube river basin
	5	Small rivers downstream of karst spring/Carbonate Alps of the Danube river basin
	6	Small rivers downstream of limnocrene spring/Carbonate Alps of the Danube river basin
	7	Small intermittent rivers/Carbonate Alps of the Danube river basin
	8	Medium-sized rivers/Carbonate Alps of the Danube river basin
	9	Medium-sized rivers downstream of lake/Carbonate Alps of the Danube river basin
	10	Medium-sized rivers downstream of karst spring/Carbonate Alps of the Danube river basin
	11	Small rivers/Silicate Alps
	12	Small mountainous rivers/Silicate Alps
	13	Medium-sized rivers/Silicate Alps
	14	Small rivers/Subalpine hills of the Danube river basin
	15	Small rivers downstream of karst spring/Subalpine hills of the Danube river basin
	16	Small intermittent rivers/Subalpine hills of the Danube river basin
	17	Medium-sized rivers/Subalpine hills of the Danube river basin
	18	Small rivers/Carbonate Alps of the Adriatic river basin
	19	Small mountainous rivers/Carbonate Alps of the Adriatic river basin
	20	Small rivers downstream of karst spring/Carbonate Alps of the Adriatic river basin
	21	Medium-sized rivers/Carbonate Alps of the Adriatic river basin
	22	Medium-sized rivers downstream of karst spring/Carbonate Alps of the Adriatic river basin
	23	Small rivers/Subalpine hills of the Adriatic river basin
	24	Small rivers downstream of karst spring/Subalpine hills of the Adriatic river basin
	25	Small meandering rivers/Subalpine hills of the Adriatic river basin
	26	Medium-sized rivers/Subalpine hills of the Adriatic river basin
	27	Medium-sized rivers downstream of karst spring/Subalpine hills of the Adriatic river basin
5	28	Small rivers/Dinaric karst
	29	Small meandering rivers downstream of karst spring/Dinaric karst
	30	Small intermittent meandering rivers downstream of karst spring/Dinaric karst
	31	Small intermittent rivers downstream of karst spring/Dinaric karst
	32	Small periodically flooding rivers/Dinaric karst
	33	Medium-sized meandering rivers downstream of karst spring/Dinaric karst
	34	Medium-sized intermittent meandering rivers downstream of karst spring/Dinaric karst
	35	Medium-sized periodically flooding rivers/Dinaric karst
	36	Small rivers/Dinaric mountains

Eco-region	Type no.	River type name
	37	Small rivers downstream of karst spring/Dinaric mountains
	38	Medium-sized rivers downstream of karst spring/Dinaric mountains
	39	Small rivers/Subdinaric hills and plains
	40	Small meandering rivers downstream of karst spring/Subdinaric hills and plains
	41	Small meandering rivers/Subdinaric hills and plains
	42	Small intermittent rivers downstream of karst spring/Subdinaric hills and plains
	43	Medium-sized rivers/Subdinaric hills and plains
	44	Medium-sized rivers downstream of karst spring/Subdinaric hills and plains
	45	Medium-sized meandering rivers downstream of karst spring/Subdinaric hills and plains
	46	Medium-sized meandering rivers/Subdinaric hills and plains
	47	Medium to large rivers downstream of karst spring/Subdinaric hills and plains
	48	Medium to large meandering rivers/Subdinaric hills and plains
	49	Small rivers/Submediterranean hills without surface outflow
	50	Small intermittent rivers/Submediterranean hills without surface outflow
	51	Medium-sized rivers/Submediterranean hills without surface outflow
	52	Medium-sized intermittent rivers/Submediterranean hills without surface outflow
	53	Small rivers/Submediterranean hills with surface outflow
	54	Small intermittent rivers/Submediterranean hills with surface outflow
	55	Medium-sized rivers downstream of karst spring/Submediterranean hills with surface outflow
	56	Small intermittent rivers/Coastal hills
11	57	Small rivers/Pannonian hills and plains
	58	Medium-sized rivers/Pannonian hills and plains
	59	Small rivers/Pannonian plains with alpine influence
	60	Medium-sized rivers/Pannonian plains with alpine influence
	61	Medium to large rivers/Pannonian plains with alpine influence
	62	Small rivers/Krško-Brežice basin
	63	Medium-sized rivers/Krško-Brežice basin
	64	Medium to large rivers/Krško-Brežice basin
Large	65	Alpine Sava River
rivers	66	Soča River
	67	Dinaric Sava River
	68	Ljubljanica River
	69	Kolpa River
	70	Pannonian Sava River-braided
	71	Pannonian Sava River-non-braided
	72	Krka River
	73	Interalpine Drava River
	74	Mura River and Plain Drava River