Study Series within the Campaign:

The Huchen *Hucho hucho* in the Balkan region

Distribution and future impacts by hydropower development

Prepared by

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Young, male Huchen *Hucho hucho* © A. Hartl (Title Page)

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1.Summary

The Huchen or Danube Salmon is one of the most enigmatic species of Europe's freshwater fauna. It is a sensitive indicator species for some of the most ecologically valuable rivers in the Danube drainage. Historically, the species was wide-spread across the entire Danube basin. Since the late 19th century, however, Huchen populations declined by two thirds and the remaining populations are now highly endangered by hydropower development. But knowledge on the distribution of the Huchen on the Balkan Peninsula has been incomplete. In this study, we review the actual occurrence of Huchen in the Balkan region. A total of **1842 river km supporting self-sustaining populations** of Huchen in the Balkan region have been identified, **making the region the global hot spot for the species**. These populations are found in 43 rivers or distinct river reaches in Slovenia, Croatia, Bosnia-Herzegovina, Serbia and Montenegro. About 65% of all Huchen rivers globally are located in these countries, highlighting the importance of Balkan Rivers for the survival of the species. Core areas, representing the largest and healthiest Huchen populations have been identified for each country and include the **Sava River** and its tributaries in Slovenia, the **Kolpa / Kupa River** along the Slovenian-Croatian border, the **Una River** along the Croatian-Bosnian-Herzegovinian border, the upper **Drina River** and its tributaries in Bosnia-Herzegovina and Serbia, and the **Lim River** in Montenegro. The Balkans harbour nearly all major habitats for Huchen in terms of size. In this region we find six of the seven > 100 km long river reaches representing Huchen habitat globally (Sava, Kolpa/Kupa, Una, Sana, Drina & Lim rivers).

The major threat to these populations is a massive hydropower development plan. Practically all Huchen Rivers are targets of substantial hydropower exploitation. **A total of 93 dam projects** were identified directly in river reaches supporting Huchen and a large number of additional projects are located in tributaries or headwater reaches upstream of Huchen habitat that will invariably degrade environmental conditions downstream. If these dams would be constructed**, at least 1.000 km of Huchen habitat** would be drowned by reservoirs or severely degraded by hydropeaking below the dams. If these plans are carried out, **we predict that at least 60-70% of the Balkan population and about 35-40% of the global population of Huchen would be lost** with the remaining populations being small and severely fragmented and eventually no longer able to survive in the long term.

We urge that the remaining free-flowing Balkan rivers holding self-sustaining populations of Huchen be left undammed, and efforts be made to restore former rivers reaches where Huchen once occurred but are now absent. We emphasize that Huchen, as an apex predator, is an indicator of relatively healthy riverine ecosystems. These systems provide a number of ecosystem services and are home to a large number of species, including at least 16 fish (such as the sculpin, zingel and streber) that at are themselves legislatively protected. **The existence of Huchen and these species with such hydropower development is incompatible.**

For governments, this data is paramount to fulfilling their conservation commitments, as the Huchen is protected by the EU Natura Habitats Directive and the Bern Convention and is a key species for achieving the goals of the EU Water Framework Directive.

2. Introduction

This study focuses on the Huchen or Danube salmon *Hucho hucho*, a freshwater fish endemic to the Danube drainage, where it once occurred in all major tributaries and parts of the Danube itself. With a maximum total length of up to 183 cm and a weight of up to 60 kg (Holčík et al., 1988), it belongs to the enigmatic freshwater megafauna of the area; in Europe, only sturgeons *Acipenser* spp. and wels *Silurus glanis* grow larger. Huchen has been assessed by the *The IUCN Red List of Threatened Species™* as being Endangered (Freyhof & Kottelat 2008) and it is one of very few globally threatened fish species in the Danube catchment. Holčík et al. (1988), Kottelat & Freyhof (2007) and most recently Ihut et al. (2014) compiled biological data on Huchen. Huchen inhabit montane and submontane reaches of large streams and swift rivers with gravel beds, well oxygenated, fast-flowing water and temperatures rarely above a mean July temperature of 15°C. It prefers deep pools and spawns in very clean gravel in fast-flowing water, often in small river tributaries. Huchen is usually restricted to running water of rivers, where it hunts as an ambush predator.

Holčík et al. (1988) and Witkowski et al. (2013) point out that Huchen is highly sensitive to various human impacts and is a good indicator for river health. Huchen is sensitive to low oxygen and moderate levels of pollution. Their large size makes them a target of both legal and illegal fisheries and as a large apex predator, healthy Huchen populations need considerable space and available prey. As Huchen prefer relatively low water temperatures, they are also sensitive to climate change (Ratschan, 2014).

A pair of spawning Huchen © Clemens Ratschan

Holčík et al. (1988), Witkowski et al. (2013) and Ratschan (2014) stress that Huchen need free-flowing rivers with clean water and are very sensitive to hydropower exploitation. Holčík et al. (1988) estimates the Huchen inhabit just 33% of its original global distribution range. The species has continued to decline since. In the last 30 years, many new dams have been built in the Danube drainage and hydropower development is booming throughout the

region. The large scale loss of Huchen populations in the recent past implies that the data compiled by Holčík et al. (1988) (Figure 3) are no longer valid. Most published data on Huchen, including information on its distribution stem from Central Europe, in Austria, Germany and Slovakia. Until now, no detailed survey of Huchen distribution exists and outside of some anecdotal comments in Witkowski et al. (2013) and Ihut et al. (2014), little to no information exists on the distribution of Huchen in the Balkan region. This data is of paramount importance for regional governments in fulfilling their conservation commitments, as the species is protected by the EU Natura Habitats Directive and the Bern Convention and is a key indicator for achieving the goals of EU's Water Framework Directive. This study provides a current and comprehensive assessment of Huchen distribution in the Balkan region.

3.Methods

Huchen is assessed at two different scales. First, river stretches inhabited by Huchen are detailed for the Balkan region, specifically for Slovenia, Croatia, Bosnia-Herzegovina, Serbia and Montenegro. Second, this data is integrated with a less detailed summary of Huchen distribution for the rest of the Danube drainage outside the Balkan region.
For the Balkan survey, the study began with a 3-day workshop assembling 18 academic and government experts from throughout the target region. The workshop aimed to gather all published or unpublished literature and reports on the current status of Huchen in Balkan rivers, and to construct a detailed map of documented occurrence, in the sense of self-sustaining populations. This criterion was based on documentation of all life-history stages (juvenile, adult, access-to-spawning grounds) and not simply anecdotal occurrence, which could reflect merely hatchery-reared supplementation.

A map was constructed of Huchen distribution and additional emphasis was placed on identifying the ranges of all self-sustaining Huchen populations for each country (Figure 1). Where available we collected additional information on population trends (i.e. stable, declining, or increasing). This map of Huchen distribution was additionally overlaid with a map of both existing and planned hydropower schemes (Figure 2) in order to assess the potential future threats to Huchen in the region.

Summary statistics on Huchen distribution and threats in the Balkan region were integrated with published data on the species distribution throughout the Danube catchment, in order to assess the role of the Balkan rivers in the species long-term conservation status. A brief summary of legislation relevant for Huchen conservation is presented including the potential legislative conflict arising from these laws and hydropower expansion in the Balkan region.

To estimate the threat of hydropower exploitation on the Huchen, we differentiated between existing projects with rivers holding Huchen, planned projects directly in Huchen habitat, and planned projects outside of Huchen habitat, but with consideration on their larger-scale effects.

4. Results

4.1. Balkan distribution area

A total of 1842 river km in the Balkan region have been identified as carrying self-sustaining populations of Huchen (Table 1). These populations are found in 43 river sections in Slovenia, Croatia, Bosnia-Herzegovina, Serbia and Montenegro. The most important river in terms of habitat length is the Drina together with its major tributaries the Lim and Tara, totalling 30% (553 km) of the Balkan Huchen distribution.

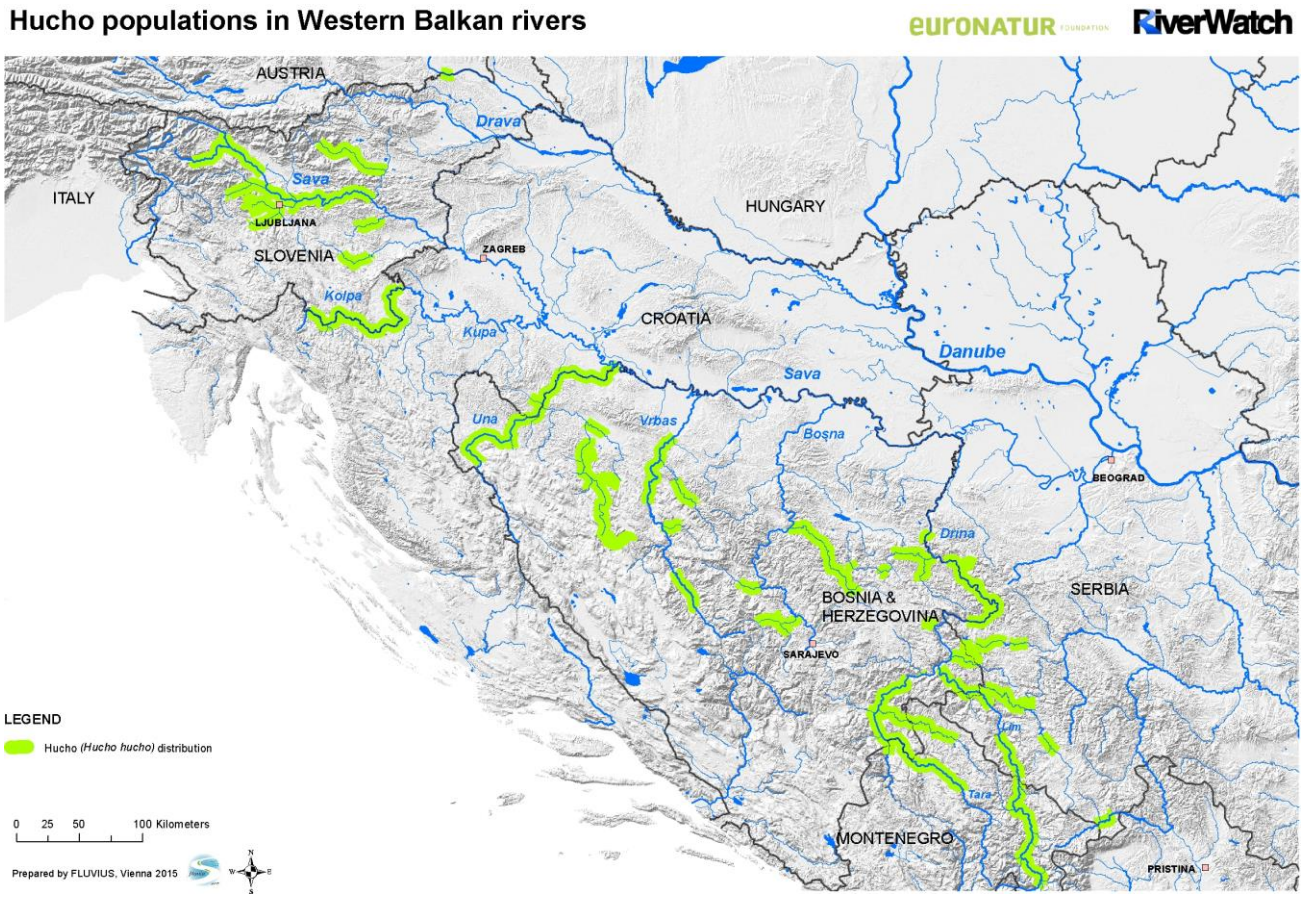

Figure 1. Distribution of self-sustaining Huchen populations in the Balkan region.

For the Balkan region, by country, and counting border rivers twice, 1072 km of the total habitat is found in Bosnia-Herzegovina, 456 km in Slovenia, 391 km in Serbia, 240 km in Montenegro, and 228 km in Croatia.

Population trend information was recorded for 34 (1630 km) of the 43 river sections (Table 1). Of these, approximately 42% (688 km) were considered to support populations that were stable, 22% (354 km) increasing and 36% (588 km) decreasing. Twelve (28%) of the 43 river sections were < 10 km in length representing primarily spawning areas for larger rivers,

and not viable populations themselves, and 17 (40%) of all river sections were less than 20 km in length and thus unlikely to represent long-term viable populations without gene flow (connectivity) from other populations. It was not possible in the context of this study to evaluate the quality of many of these rivers, and the reported densities of fish ranged widely.

Table 1. River sections in the Balkan region containing self-sustainable Huchen populations. Numbers (Nr) correspond to Figure 2.

Nr	Country	River	Catchment	Length km	Population trend
1	Slovenia	Sava Bohinjka	Sava	26	Stable
2	Slovenia	Sora (Pojanska)	Sava	31	Stable
3	Slovenia	Ljubljanica	Sava	38	Decreasing
4	Slovenia	Sava	Sava	118	Decreasing
5	Slovenia	Krka	Sava	27	Stable
6	Slovenia	Mirna	Sava	7	Decreasing
7	Slovenia	Savinja	Sava	49	Stable
8	Slovenia	Drava	Drava	33	Decreasing
9	Slovenia / Croatia	Kolpa/Kupa	Kupa	106	Stable
10	Croatia / Bosnia-Herzegovina	Una	Una	122	Increasing
11	Bosnia-Herzegovina	Klokot	Una	4	Stable
12	Bosnia-Herzegovina	Gomjenica	Una	12	Stable
13	Bosnia-Herzegovina	Sana	Una	109	Stable
14	Bosnia-Herzegovina	Kozica	Una	6	/
15	Bosnia-Herzegovina	Sanica	Una	6	/
16	Bosnia-Herzegovina	Vrbas	Vrbas	90	Stable
17	Bosnia-Herzegovina	Vrbanja	Vrbas	26	Decreasing
18	Bosnia-Herzegovina	Ugar	Vrbas	6	/
19	Bosnia-Herzegovina	upper Vrbas	Vrbas	60	Stable
20	Bosnia-Herzegovina	Lašva	Bosna	18	Decreasing
21	Bosnia-Herzegovina	Mlava, Lepenica, Fojnica	Bosna	53	Decreasing
22	Bosnia-Herzegovina	Krivaja, Očevica	Bosna	75	Increasing
23	Bosnia-Herzegovina	upper Drinjača	Drina	10	Stable
24	Bosnia-Herzegovina	upper Drinjača	Drina	6	Stable
25	Bosnia-Herzegovina	Drinjača	Drina	18	Stable
26	Bosnia-Herzegovina	Jadar	Drina	17	/
27	Bosnia-Herzegovina	Stupčanica	Drina	6	/
28	Serbia	Gornja Trešnjica	Drina	3	Decreasing

29	Serbia	Drina	Drina	147	/
30	Bosnia-Herzegovina	Prača	Drina	3	/
31	Serbia	Đetinja	Zapadna Morava	10	Stable
32	Serbia	Rogačica	Drina	4	Decreasing
33	Bosnia-Herzegovina	Rzav	Drina	17	/
34	Serbia	Uvac	Drina	5	Decreasing
35	Bosnia and Herzegovina	Lim, Poblačnica	Drina	65	Stable
36	Bosnia-Herzegovina	Drina	Drina	114	Decreasing
37	Bosnia-Herzegovina	Bistrica	Drina	4	/
38	Bosnia-Herzegovina, Montenegro	Ćehotina	Drina	65	Stable
39	Montenegro / Bosnia-Herzegovina	Piva, Sutjeska	Drina	13	Decreasing
40	Montenegro	Tara	Drina	70	Decreasing
41	Serbia, / Montenegro	Lim	Drina	157	Increasing
42	Serbia	Vapa	Drina	45	Decreasing
43	Serbia	Ibar	Zapadna Morava	20	Decreasing

These individual river stretches are found across seven major river basins, with 42% (796 km) found in the Drina catchment (Table 2). The largest and most important Huchen rivers for the Balkan region, for each country, are the **Sava** for Slovenia, the **Kolpa / Kupa** (Slovenia/Croatia), the **Una** (Croatia/Bosnia-Herzegovina), the **Sana** (Bosnia-Herzegovina), the **Drina River** (Bosnia-Herzegovina & Serbia), and the **Lim River** in Montenegro and Serbia (Table 1). Additional rivers of significant size or presumed quality include the Ćehotina in Montenegro and Bosnia-Herzegovina, the Vrbas, Krivaja and Fojnica in Bosnia-Herzegovina, and the Savinja in Slovenia. Additional tributaries of these rivers often harbour smaller populations or act as spawning grounds for populations in the main rivers.

Table 2. Length (km) of Huchen habitats in major river catchments (see Table 1) in the Balkan region.

Tributary	**Bosna**	**Drava**	**Drina**	**Kolpa/Kupa**	**Sava**	**Una**	**Vrbas**	**Zapadna Morava**
Km	146	33	769	106	317	259	182	30

Kupa/Kolpa River (Slo/HR) © Pedrag Simonovic

4.2. Hydropower assessment

About 30 major existing hydropower plants were identified in rivers either previously or currently supporting Huchen populations (Figure 2). Most of these facilities exist in reaches where there are no longer Huchen, such as the Drava and lower Sava rivers in Slovenia, and the 106 km-long Dobra River in Croatia, where Huchen have been completely eliminated due to hydropower development. Other significant existing hydropower plants are found in systems where Huchen still survive in major undammed tributaries or in connection with large free-flowing reaches upstream or downstream from the impoundment area. Such systems include the Vrbas in Bosnia-Herzegovina, the lower and middle Drina along the Serbian-Bosnian and Herzegovinian border, and the Lim and Cehotina rivers in Montenegro.

A total of 93 hydropower schemes are newly planned directly in rivers holding self-sustaining Huchen populations (Figure 2) that would negatively affect Huchen and their associated fauna through the combined effects of transforming the river into a reservoir, hydropeaking, sediment retention or flushing, migration barriers and alterations in temperature regimes. These schemes are distributed across five countries with 41 (44%) found in Bosnia-Herzegovina (see Appendix A2). They vary in size, with 42 plants ranging from 1-10 MW peak load, 38 from 10-50 MW and 13 > 50 MW.

All major river reaches characterized here as Huchen habitat are under direct threat of destruction or the negative effects of hydropower expansion. Table 3 as well as Tables 4-6 in the Appendix provides an overview on the planned hydropower dams within the Balkan distribution area of Huchen. If these dams were constructed, at least 1.000 km of Huchen habitat would be drowned by reservoirs or severely degraded by hydropeaking below the dams.

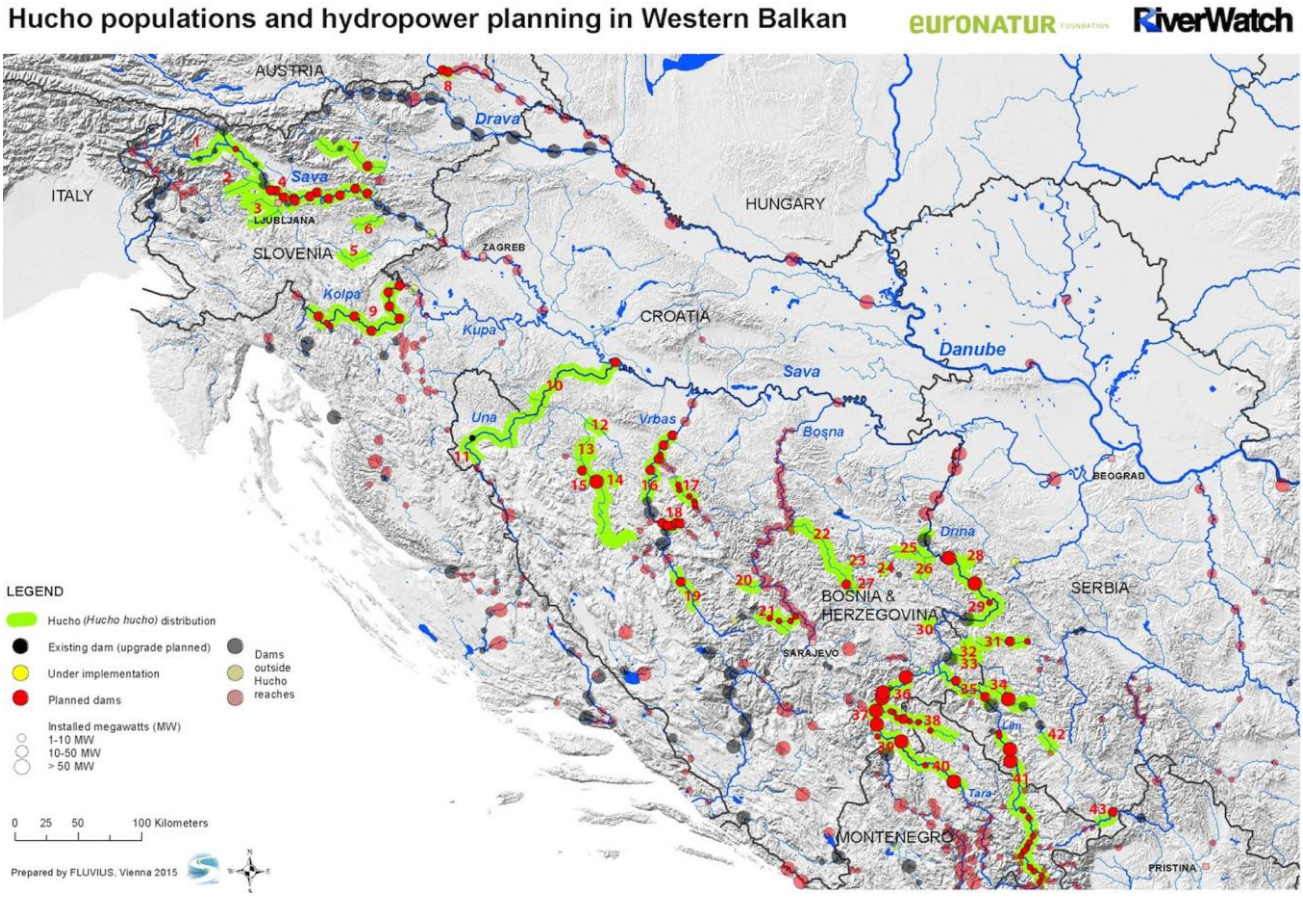

Figure 2. Distribution of self-sustaining Huchen populations and existing as well as potential future hydropower plants in the Balkan region. Numbers correspond to Table 1.

Table. 3. Future hydropower dams in the rivers of Balkan region reaches supporting Huchen.

River sub-basin	**Number of dams planned**
Mur-Drava	2 (border Mur)
Upper Sava	12 (10 directly on the upper Sava)
Kolpa/Kupa	9 (7 directly on the Kolpa/Kupa)
Una	4 (one on Una but only extension of existing dam, one directly at the mouth, but in the Sava)
Vrbas	17 (6 directly on the upper Vrbas)
Bosna	5 (many additional in the Bosna itself)
Drina	41 (8 directly on the Drina)
Zapadna Morava	3
Total	**93**

Major rivers that currently do not hold self-sustaining populations due to poor water quality, but could be potentially rehabilitated, such as the Bosna River in Bosnia-Herzegovina, are about to be slated for complete hydropower exploitation.

5. Discussion

5.1 Non-Balkan distribution area

A total of 1011 river km, or 35% of the global distribution of Huchen habitat is found outside the Balkan region. By country, Slovakia contains 14% (413 km), Germany 7% (200 km), Austria 7% (198 km), Ukraine 6% (170 km), and Romania 1% (30 km) of the global distribution. Witkowski et al. (2013) reported distribution of Huchen in Ukraine, including stretches along an approximately 170 km stretch of the Tisza drainage; details of occurrence in the Prut drainage are unknown, but the species still survives there. In Romania, some tributaries of the Vişeu (10 km total) in the Maramures region, also part of the Tisza drainage, still support Huchen (Witkowski et al. (2013). Huchen is still present in the upper Bistriţa River (Ihut et al., 2014) (maybe 20 km total). Virtually all of the populations once known from Romania are gone. Bănărescu (1964) still reported Huchen populations from the Vişeu, Vaser, Novăţ, Ruscova, Bistriţa Moldovenească, Dorna, Suceava and Moldova rivers in Romania; today only the Vişeu and Bistriţa remain. About 80% of its historic range in Slovakia (2039 km) has been lost (Jan Kosco, pers. comm.). Self-sustaining populations of Huchen are thought to occur in 413 river km today (Jan Kosco, pers. comm.), with the Vâh River (238 km) and its tributaries representing by far the longest reported Huchen habitat outside of the Balkan region. Following the Vâh, the Mur River in Austria is the second largest Huchen habitat outside of the Balkan region (at least 97 km of habitat), hosting about 1500 adult fishes. Ratschan (2014) reviews in detail the actual distribution of the species in Austria and reported small reproducing populations in the Pielach, Melk and Mank rivers (together 41 km) (see also Schmutz et al., 2002). Additional to isolated populations in several smaller rivers of the Mur and Enns drainages (Ratschan 2014), self-sustaining populations are also known from the Gail (60 km), a tributary of the Drava, and a recently shortened reach of the Mur around Graz (10 km, immediately threatened by newly approved hydropower schemes) (Weiss & Schenekar, 2012). Austrian has lost 90% of its historical distribution and similar historical losses are known from Germany, where the longest river reach believed to hold a self-sustaining population is the upper Isar (50 km) (von Siemens, pers. comm.).

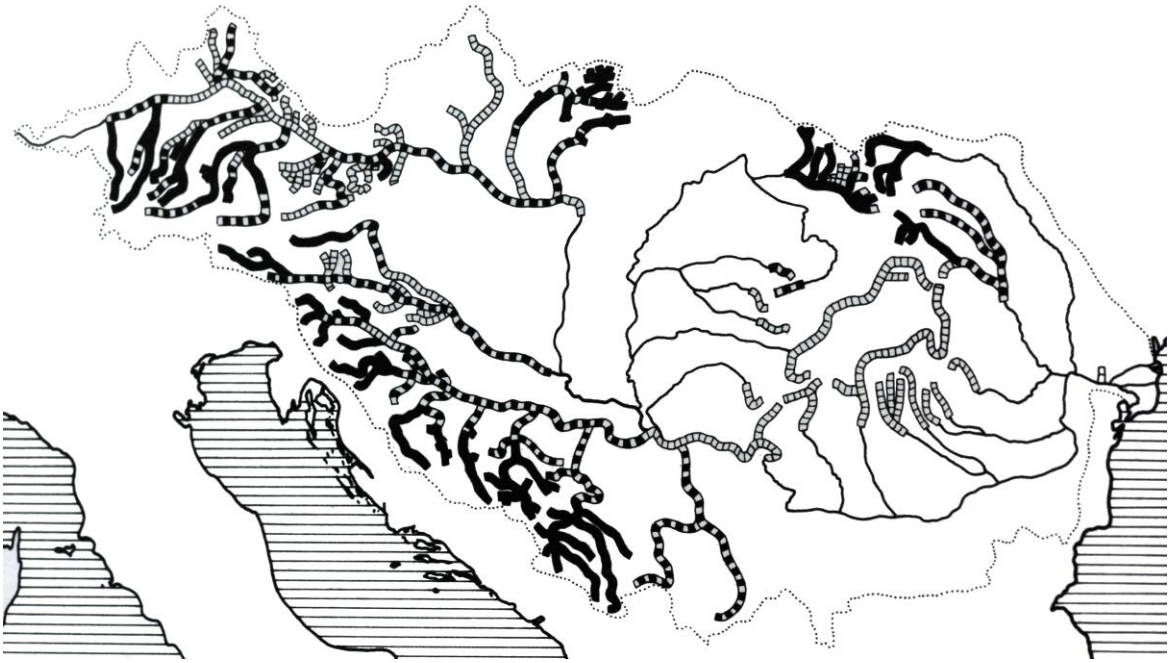

Figure 3. Distribution of Huchen populations in the Danube drainage modified from Holčík et al. (1988). Solid black squares indicate present permanent occurrence, black and grey squares indicate present sporadic occurrence and grey squares indicate historically documented past occurrence. Modified by Holčík et al. (1988).

5.2 Balkan distribution area

Since the late 19th century, Huchen have been eliminated from approximately 70-90% of their native range. However, decline in the Balkan region has been moderate by comparison (ca. 35%, or about 1000 km), with the majority of the species' remaining intact habitat found in this region. While hydropower development is already responsible for considerable loss of habitat in the Balkan region (e.g. the Dobra and Drava Rivers in Croatia, the Zapadna Morava River in Serbia, parts of the Drina River drainage in Serbia, the Piva River in Montenegro, or the lower Drava and lower Sava in Slovenia), much of the historical decline is thought to be the result of pollution. Pollution is still a major problem in the Bosna and in parts of the Vrbas rivers in Bosnia-Herzegovina. The Zapadna Morava River and its tributaries was once a large Huchen habitat, but almost all Huchen populations have been lost. The Zapadna Morava is polluted through most of its length, as well as the Ibar River, its largest tributary. Actually, there is just one small Huchen population in the entire Zapadna Morava drainage, which is threatened with extirpation due to a planned hydropower dam. Overfishing is also a considerable problem in some regions (especially in the Drina). **Habitats lost by pollution and overfishing could be restored**. In some rivers in Montenegro, for example, increased awareness and the economic benefits of tourist fisheries have helped to bring some of the illegal fishing in that region under control, resulting in stable or even increased Huchen and grayling stocks, in the Lim and Ćehotina rivers, the latter considered Montenegro's best current Huchen habitat.

Sava Bohinjka (SLO) © Miha Ivanc

The Balkan region harbour not only the majority of remaining Huchen habitat, but also the overwhelming majority of all major habitats in terms of size – six of seven of > 100 km long river reaches representing Huchen habitat globally (Sava, Kolpa / Kupa, Una, Sana, Drina & Lim rivers) are found in the Balkan region. Huchen is both a flagship and indicator species for a whole community of montane freshwater biota including a high number of invertebrates, and often live in sympatry with up to 16 EU Natura Habitats Directive protected species such as sculpin, *Cottus gobio*, Danubian brook lamprey *Eudontomyzon vladykovi*, large-spot barbel *Barbus balcanicus*, Danube whitefin gudgeon *Romanogobio vladykovi*, sand gudgeon *Romanogobio kesslerii*, stone gudgeon *Romanogobio uranoscopus*, yellow pope *Gymnocephalus schraetser*, asp *Leuciscus aspius*, Balkan golden loach *Sabanejewia balcanica*, Pontian shemaya *Alburnus sarmaticus,* riffle dace *Telestes souffia*, cactus roach *Rutilus virgo*, Danubian spined loach *Cobitis elongatoides*, Balkan spined loach *Cobitis elongata*, streber *Zingel streber* and zingel *Z. zingel*. All of these species as well as regionally threatened or economically important species such as, brown trout *Salmo trutta* and grayling *Thymallus thymallus* benefit from the conservation of Huchen habitats. Maybe the most important river where Huchen and all these species are found is the Kupa / Kolpa, which is one of the rivers in the Danube drainage of exceptionally rich biodiversity.

Of the six > 100 km river reaches in the Balkans sustaining Huchen, all are targeted with major hydropower exploitation, in most cases detrimentally affecting the entire habitat reach.

Additionally, except for the Una River in Bosnia-Herzegovina where only limited hydropower development is foreseen, each country's core Huchen habitat is threatened in its entirety by hydropower exploitation (Table 3). By country, nearly all of Slovenia's Huchen habitat, and all of Montenegro's Huchen habitat is threatened by planned hydropower expansion and the very last Huchen population in the Zapadna Morava drainage will be lost.

Una River (HR/BIH) © Goran Jaksic

5.3 Hydropower threats

Generalizations concerning the effects of hydropower on aquatic fauna are complicated by unique environmental characteristics of different rivers, varied species sensitivities and varied technological designs and operating priorities of different hydropower schemes. In the Balkan region, hydropower plans range from numerous micro-facilities in tributaries of Huchen rivers, which can block their access to spawning grounds, on up to various run-of-the-river schemes or larger storage plants with dams built directly in a river's main channel. **All such dams result in direct degradation or destruction of riverine habitat at the dam and for the length of the reservoir behind the dam, at a minimum.** The construction of a reservoir transforms a river into a lake, often with unnaturally fluctuating water levels. The invertebrate fauna on the bottom of a reservoir is massively reduced both in terms of species diversity and biological productivity, rheophilic fish species are either completely eliminated or severely reduced in numbers. Large impoundments are unnatural habitats that are wholly

unsuitable for Huchen to complete its life cycle. Dams without fish pass facilities establish a migration barrier for fishes. Experience show, that Huchen have major problems with most fish pass facilities and are either unable to use them at all, or at a very low efficiency. Thus far, most standard fish pass facilities fail to provide for Huchen migration, due to the behaviour of the fish and the large size of Huchen. Even with fish pass facilities, both up and downstream migration of particular species or life-history stages are prohibited or severely reduced. For most larger dams, no fish pass facilities can be effectively constructed due to the competition for water between hydropower or the fish pass. **The existence of Huchen and such hydropower development is incompatible.**

All storage plant facilities are operated with at least some, and often a significant amount of hydropeaking. Hydropeaking is the fluctuating release of different volumes of water through turbines in order to meet fluctuating demands in energy use or to deal with too limited discharge of rivers for continuous power production. **Hydropeaking is perhaps the most extensive (in area) and difficult to mitigate impact of storage or pump-storage hydropower schemes on riverine fauna.** Fluctuating water levels of up to a meter or more are released (typically) daily or two times per day during peak demand. Few aquatic fauna can adapt to such conditions, and above all these fluctuating water levels severely degrade or eliminate reproduction or early-life history stages of many fish species. The larger the dam or the higher the hydropeaking, the more river kilometres are affected. For example, storage hydropower facilities in Switzerland severely degrade the long reaches of the upper Inn River in Austria across more than 100 km, creating conditions that have not only eliminated self-sustaining Huchen, but most of their associated fauna as well.

Dam on the Piva River (ME): destroyed Huchen habitat © Steven Weiss

The combined effects of hydropeaking and reservoir flushing can also lead to the promotion of river bed colmation – essentially the clogging of interstitial space in the river substrate, **which chokes out invertebrate life and eliminates spawning grounds**. Colmation can be very severe, but varies from river to river depending on specific characteristics of the system. **Dams further create sediment deficits, resulting in river bed erosion (sinking of the river bed), loss of gravel bars and sand banks, and a reduction or change in the overall morphological dynamics of the system.** Long-term this can further lead to isolation of tributaries from the main stem of the river, dropping groundwater tables and reduction or attrition of wetland and riparian agricultural area. Larger storage facilities are seldom equipped with the capacity to flush fine sediments from their reservoirs, but when they do, such **flushing often results in acute or even catastrophic kills of aquatic life below the dam, often for many kilometres depending on the size of the flushing event.**

Run-off-the-river hydropower schemes are often operated without hydropeaking, but larger facilities, especially in chains, can be operated with very small-scale hydropeaking, especially in an increasingly competitive energy market. A chain of run-of-the-river hydropower plants on the Mur River in Graz, though not licensed to do so, operates with systematically timed hydropeaking resulting in about 50 cm of water-level fluctuation, twice daily. Such fluctuations leave spawning and rearing areas in gravel banks or side channel habitats dry, on a daily basis. While some adult fishes can adapt to such fluctuations, reproduction is severely impacted and usually inhibited. Smaller run-of-the-river schemes are nowadays often equipped with flushing capacity, or are routinely opened during floods, especially in more developed areas were dam overflows could threaten settlements. While flushing temporarily improves reservoir conditions, and brings at least fine sediments back into the system, these events often result directly in fish kills, especially for early-life history stages – as these events are seldom planned, they can occur any time of year, resulting in reproductive drop out of different species in different years, downstream of the dam.

Some run-of-the-river schemes involve diversion channels, leaving relatively little water left in the main channel. While residual flow requirements (most often only a small fraction of the annual mean flow) prevent the complete drying out of abstracted river reaches, a very large reduction in habitat area can occur, overall flow variation is increased, and the prey base and overall productivity is reduced making it extremely difficult for top predators such as the Huchen to survive.

For rheophilic species such as Huchen and much of their associated fauna, reservoirs are not considered viable habitat for their complete life history cycle. Huchen are found in some larger reservoirs, but only when spawning and rearing habitats in tributaries or upstream regions are accessible, and sufficient prey base is available. In heavily developed areas of Central Europe, hydropower reservoirs only very rarely contain Huchen. Three key issues are relevant when discussing the occurrence of Huchen in reservoirs. **First**, the water quality must be sufficient, with high oxygen levels and low water temperatures. Summer-warm or polluted reservoirs are not inhabited by huchen. **Second**, there must be a high abundance of forage fishes in the reservoir. Like huchen, many of its main prey species such as nase *Chondrostoma nasus*, barbels *Barbus* spp. and grayling *Thymallus thymallus* often have problems to find food themselves in reservoirs and might avoid these, especially if the

bottom consists of sand, silt or mud. **Third**, there needs to be a free connection to suitable spawning grounds. Spawning grounds are never situated in reservoirs but in flowing rivers and streams. In large river sections affected by hydropeaking and/or reservoir flushing, Huchen are often absent completely. As noted for the Inn River in Austria, such affects can and do extend over 100 km.

Huchen © A. Hartl

Overall, large-scale hydropower development results in a massive alteration to the natural dynamics of a river ecosystem, as well as additional often unpredictable negative effects on the surrounding environment, including groundwater supplies, flood control and other water-use conflicts. The topic of scale concerning hydropower impacts is an important issue. Whereas there is considerably more concern for the environmental or social impacts of large-scale hydropower projects, small-scale plants are often thought to be harmless. Any power plant, in an ecologically sensitive place (such as a spawning area or migration corridor) can severely impact a species such as Huchen. Small scale plants do have serious effects on a system, when for example a large reach of the river is turned into a residual flow (diversion plants), or in sensitive systems where the sediment, flow, or temperature regime is impacted. Additionally, experience demonstrates that chains of even smaller run-of-the-river plants can eliminate species such as Huchen, and severely reduce the overall productivity of the system, as the frequency of disturbance events (such as reservoir flushing) and cumulative or synergistic effects of even partial migration barriers can be detrimental to many species.

Generally, small hydropower plants might have a smaller negative effect on Huchen populations than larger ones as the affected area is smaller. But small hydropower plants produce less energy and thus more dams are needed, which are often constructed in chains or near key spawning areas and thus can eliminate sensitive species such as Huchen. Therefore, any hydropower development in Huchen habitat is incompatible with their long-term survival.

5.4 Other Threats

Overfishing. Overfishing or illegal poaching was the major threat to Huchen historically (Holčík et al., 1988) and is still a local problem in some Balkan rivers, especially in Bosnia-Herzegovina, Serbia and Montenegro. As economic conditions improve, however, and tourism continues to increase, illegal fishing can be brought under control, and populations in intact habitats can quickly recover. This has been the case in, for example the Lim and Ćehotina rivers in Montenegro and the Drina in Serbia and Bosnia-Herzegovina. The regional economic benefits of a sport fishery far exceed those of poaching.

Pollution. Pollution was a major historical cause for the decline of Huchen in the late 19th and throughout the 20th century. North of the Balkan region most rivers have experienced major improvement in water quality so pollution is no longer considered a major threat (Witkowski et al. 2013). Still, pollution is listed as a major current problem in some (but not all) Balkan rivers, such as the Bosna in Bosnia-Herzegovina.

Habitat degradation. Habitat degradation not necessarily associated with hydropower or water pollution includes channel dredging or regulation associated with improving shipping lanes, flood control measures or the stabilization of agricultural lands. In some local areas, gravel extraction can also constitute a significant habitat impact. Water diversion for agricultural irrigation can also constitute a significant impact in some regions. Witkowski et al. (2013) and Ihut et al. (2014) consider habitat degradation through various river engineering including hydropower development or water exploitation activities to be the most important threat to Huchen and their associated aquatic community. While non-hydropower related exploitation has been an important factor in non-Balkan rivers, and locally for some rivers in the present, overall, Balkan rivers not experiencing hydropower development are generally intact – i.e. their channel morphology, riparian area and river bed structure is largely natural. Currently, the expert panel strongly agrees that hydropower exploitation is the number one threat to the species in the Balkan region.

Climate change. Ratschan (2014) discussed the effects of climate change on several local Huchen populations in Austria. He reports summer kills of Huchen from the river Pielach. The effects of climate change have been much discussed but presently, especially for the Balkan region, there is a lack of reference data or reliable models to make any serious prediction on the potential effects of climate on the species in the region.

Inbreeding, Genetics and Mismanagement. As a large apex predator, healthy Huchen populations need considerable space, with only 10 adult individuals typically in one km of river

for a medium sized river (Ratschan, 2014). Many smaller habitats listed here (10 rivers) are noted to be spawning sites only and are not permanently inhabited by adults. Only 10 listed river stretches are longer than 50 km and could be expected to hold more than 500 adult Huchen. A rule-of-thumb for avoiding long-term inbreeding is a minimum of 500 breeders but these numbers have been called into question and new studies consider even 1000 breeders to be needed for the long term survival and adaptive capacity of species (Frankham et al. 2014). While hatchery operations are not considered to be a substitute for the conservation of natural populations, we note that typical Huchen hatcheries rarely have more than 10-15 breeders (and many much less) due to their large size, and thus are grossly deficient compared to the recommended minimum. Thus, only a small number of rivers throughout the range of the species (e.g. Sava, Kolpa / Kupa, Una, and Drina rivers) are large enough to be considered long-term viable gene pools for the species.

In general, we consider stocking to be not only an inadequate tool to manage or conserve natural populations of Huchen, but an action that all-to-often causes more harm than good in terms of genetic alterations, increased competition or predation pressure, and introduction of diseases. Reliance on large-scale stocking operations for management in systems where Huchen reproduce naturally is discouraged (see Ihut et al. 2014).

Sava River near Litija (SLO) © Miha Ivanc

5.5 Legislation

The legislative protection for Huchen has been in place for decades and is very clear. The construction of hydropower plants that degrades Huchen habitats or significantly reduces their population sizes is clearly violating specific articles of the Bern Convention**,** the EU Natura Habitats Directive and the EU Water Framework Directive (WFD). Such development is clearly a step in the wrong direction and would additionally prohibit achieving specific targets of the European Biodiversity Strategy and the Convention on Biological Diversity ratified by all countries.

- Appendix III of the **Bern Convention** lists the species as in need of protection in 1979.
- Since 1992 the Huchen is on Annex II and V of the **EU Natura Habitats Directive** and Flora and Fauna guidelines as a species of public interest, for which countries are required to designate protected areas (Natura 2000 sites) and set actions for its maintenance and rehabilitation.
- Since 2000, the **EU Water Framework Directive** (EU-WFD), barring exemptions for previously heavily modified water bodies, calls member states to maintain or improve all water bodies in a good ecological condition. Additionally, member states are forbidden (barring exemptions under §14.7 of the EU-WFD), from carrying out projects that degrade the good ecological status of water bodies.
- Conservation activities for Huchen help countries fulfil 14 of the 20 **CBD Aichi Biodiversity** (see Appendix 3 for details) **Targets**, as well as associated targets now integrated into the European Biodiversity Strategy 2020.

6. Conclusions

A total of 1842 river km in the Balkan region have been identified as carrying self-sustaining populations of Huchen. These are 65 % of the world's functional Huchen rivers. Huchen is a species that is highly sensitive to hydropower development. A total of 93 new hydropower dams are planned in rivers with Huchen populations. These hydropower schemes would destroy at least 1000 km of Huchen habitat and at least 60-70% of the Balkan population of Huchen would be lost. This development is incompatible with the conservation of Huchen and their associated fauna, and is in clear violation of existing legislation and international policies signed by the countries of the Balkan region.

Four obligations for river and Huchen conservation in the Balkan region

- No hydropower development including micro-hydropower in rivers holding self-sustaining Huchen populations including spawning streams.
- The rivers of Slovenia and Croatia, which hold Huchen populations and are not yet included in the Natura 2000 network, should all be nominated as Natura 2000 sites with the Huchen as a target species.

- Serbia, Montenegro and Bosnia-Herzegovina have to establish a Natura Habitats network in the near future and have to plan on the designation of all Huchen rivers as Natura 2000 sites. Alternatively, they should protect these rivers with the highest level of protection allowed by their domestic laws.
- A review should be made of the feasibility of restoration measures in habitats previously occupied by Huchen, without supportive stocking.

Tara River (ME). The river is threatened by 8 projected hydropower plants. © Steven Weiss

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Appendix

A 1. River stretches with Huchen distribution threaten by hydropower and their protection status. Red colour indicates hydropower planned in Huchen habitats.

Country	Position	Planned hydropower plants	Protection status (all categories)
Slovenia	Mur, border to Austria	Yes, several, as position of the distribution stretch of 10 km is unclear the first two and most realistic HPPs should be considered	Yes entirely
Slovenia	Sava Bohinjka (from lake outflow to confluence with Sava Dolinka; three existing HPP in stretch <4 MW)	No	Yes < 50%
Slovenia	Sava Dolinka (only downstream of HPP Moste)	No	Yes < 50%
Slovenia	Sava near Radovljica	Yes, one: Globoko (9 MW)	Yes entirely
Slovenia	Sava from Kranj downstream to back water of HPP Mavcice	No	Yes entirely
Slovenia	Sora from Gorenja Vas to Sava mouth	No	Yes entirely
Slovenia	Sava downstream Metvode to mouth of Savinja	Yes, nine HPP: "Tacen, Gameljne, Sentjakob, Zalog, Jevnica, Kresnice, Ponovice, Renke and Trbovlje" (all between 15 to 68 MW), "Suhadol"	Yes < 50%
Slovenia	Ljubljanica (mouth to HPP Fuzine)	Yes, one: "Ljubljanica", one existing "Varpolje" (derivation type, 2 MW)	Yes > 50%
Slovenia	Ljubljanica upstream of Ljubljana	No	Yes > 50%
Slovenia	Mali Graben and tributary	No	Yes < 50%
Slovenia	Savinja downstream Luce to Celje	Yes, one "Savinja 2"	Yes > 50% (dam in)
Slovenia	Mirna from Migolica to Gabrje	No	Yes entirely
Slovenia	Krka from upstream Zuzemberk to Novo mesto	No	Yes entirely
Slovenia /Croatia	Kolpa/Kupa (whole border area)	Yes, seven: "Kocicin, Dol, Severin, Prilisce, Stankovci, Otok and Bozakovo"	Yes entirely
Croatia	Kupica	Yes, two: "Curak, Kupica"	Yes entirely
Croatia	Zirovnica from Gornja Stupnica to mouth into	No	Yes entirely
Croatia/ Bosnia-Herzegovina	Una, entire border stretch	No, but one Sava dam "Jasenovac" could impact lower Una (most probably	Yes entirely (all BA PA's are under reconsideration, partly

Country	Position	Planned hydropower plants	Protection status (all categories)
		dam would be built upstream of Una confluence)	only planned areas)
Bosnia-Herzegovina	Una from Brekovica to Blatna	Yes, one upgrade of an existing plant "Una-Kostela-Bihac" (9 MW)	Yes > 50%
Bosnia-Herzegovina	Krusnica	No	No
Bosnia-Herzegovina	Sana from Gornji Ribnik to Nistavci	Yes, two: "Caplje and Vrhpolje"	Yes > 50%
Bosnia-Herzegovina	Sana tributary 1: Dragotinja	No	No
Bosnia-Herzegovina	Sana tributary 2: Banjica (Ratkovo to mouth)	No	No
Bosnia-Herzegovina	Sana tributary 3: Sanica (Sanica to mouth)	No	Yes entirely
Bosnia-Herzegovina	Sana tributary 4: Sasina (whole river)	No	No
Bosnia-Herzegovina	Vrbas from upstream Bugojno to Torlakovac	Yes, one: Donji Vakuf (11,5 MW)	Yes entirely
Bosnia-Herzegovina	Vrbas downstream	Yes five: "Novoselija, Banja Luka, Delibasino selo, Trn and Laktasi"	No (< 10%)
Bosnia-Herzegovina	Ugar	Yes, five in stretch: "Ugar-Usce, Ivik, Vrletna Cosa, Ugar 1 and 2"	Yes entirely
Bosnia-Herzegovina	Vrbanja from Obotnik to Celinak	Yes, six in stretch: "Jurici, Orahovo, Obodnik, Vrbanjci, Kotor Varos and Sibovi; further 6 small plants further downstream to mouth into Vrbas)	No
Bosnia-Herzegovina	Fojnica (Bosna tributary) from Plocari Polje to Dautovci)	Yes, four in stretch (names and exact position unknown, many new dams on Bosna)	Yes > 50%
Bosnia-Herzegovina	Lepenica (Foinica tributary) from Solakovici to mouth)	No (many ones in Bosna itself)	No
Bosnia-Herzegovina	Krivaja (Bosna tributary) from Boganovici to Cunista	Yes, one: "Olovo" on Biostica just upstream of Hucho reach	Yes entirely
Bosnia-Herzegovina / Montenegro	Tara (entire border stretch with ME)	Yes, one: "Bijeli Brijeg" (274 MW)	Yes entirely
Bosnia-Herzegovina / Montenegro	Piva (entire border stretch with ME)	No	Yes entirely
Bosnia-Herzegovina	Drina from origin (Tara-Piva confluence) to Gorazde (backwater begin of Visegrad dam)	Yes, five: "Bug Bijela, Foca, Paunci, Ustikolina and Gorazde, all > 50 MW)	Yes < 50%
Bosnia-Herzegovina	Sudjeska from Igoce to mouth into Drina	Yes, one: "Sudjeska" (< 10 MW)	Yes entirely

Country	Position	Planned hydropower plants	Protection status (all categories)
Bosnia-Herzegovina	Bistrica	No, but upstream catchment four and downstream close to planned Drina dam "Foca", lower course would be impounded	No
Bosnia-Herzegovina	Cehotina	Yes, five: "Milovic, Vikoc, Hreljava, Prvnice and Brioni; all 5-50 MW)	No
Bosnia-Herzegovina	Lim from border with RS to Polimlje	Yes, one: "Mrsovo (40 MW)	Yes < 50%
Bosnia-Herzegovina	Rzav (confluence Beli Rzav to mouth into Drina)	No	No
Bosnia-Herzegovina	Beli Rzav (from Rzav origin to RS border)	No	No
Bosnia-Herzegovina / Serbia	Drina downstream Bajina Basta dam to backwater begin of Zvornik dam near Crnca)	Yes, three: "Tegare and Dubravica" with > 100 MW and one small "Rogacica" < 10 MB	Yes < 50%
Bosnia-Herzegovina	Drinjaca from downstream Sucani to Drina mouth)	No	Yes entirely
Bosnia-Herzegovina	Drinjaca from downstream Ravne to Jasen	No	Yes > 50%
Bosnia-Herzegovina	Drinjaca about 10 rkm upstream Brateljevici	No	Yes entirely
Bosnia-Herzegovina	Cerska? (tributary of Drinjaca)	No	Yes entirely
Bosnia-Herzegovina / Serbia	Drina downstream Zvornik dam to Donja Borina	No (should be strongly influenced by Zvornik dam)	Yes < 50%
Serbia	Beli Rzav (from Zaovinsko reservoir to BA border)	No	Yes entirely
Serbia	Uvac from Zlatar reservoir to BA border (Lim Tributary)	Yes, one: "Bistrica" pump/storage (500 MW)	Yes > 50%
Serbia	Lim from Potpec dam to BA border	Yes, one: "Priboj" (10-50 MW)	No
Serbia	Lim upstream Potpec dam to ME border	Yes, four: "Kolovrad, Pranike and Brodarevo 1 and 2"	Yes < 50%
Serbia	Djetinja from downstream Vrutci reservoir to upstream Uzice (tributary of Zapadna Morava)	Yes, two: Just up- and downstream of reach: "Vrutci and Djetinja"	No
Serbia	Ibar from ME border to Gazivode dam backwater (tributary of Zapadna Morava)	Yes, one: "Ribarice" 50 MW	Yes entirely
Montenegro	Cehotina from Gradac to border with BA	Yes, two: "Gradac and Mekote" (both < 10 MW)	Yes entirely

Country	Position	Planned hydropower plants	Protection status (all categories)
Montenegro	Tara from upstream Gradina to upstream Tepca	Yes, two: "Ljutica (250 MW), Tepca"	Yes entirely
Montenegro	Lim from Plav to Berane	Yes, eleven: "Plavsko lake, Novsice, Murino, Bojovice, Andrijevica, Tresenjevo, Lukin Vir, Sekulari, Navotina, Rzanice, Berane and Marsenica" all < 10 MW	Yes entirely
Montenegro	Lim from Krlje to Bijelo Polje	Yes, two: "Poda and Mostine" all < 10 MW	Yes entirely
Montenegro	Lim from Strojtancia to Unevina	No	Yes entirely

A 2 Number of dams per country (double count for transboundary dams possible, compare brackets)

Country	**Number of dams planned in respective "*Hucho* reaches"**
Slovenia	21 (7 in common reach with HR)
Croatia	10 (7 in common reach with SI, one in Sava)
Bosnia-Herzegovina	41 (3 in common reach with RS, 1 with ME)
Serbia	12 (3 in common reach with BA)
Montenegro	19 (1 in common reach with BA)

A3 CBD Aichi Biodiversity targets relevant for Huchen conservation

Target 1
By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.

- *People at the rivers as well as regional and national governments are aware of the value of river biodiversity as the Huchen and also of the steps they can take to conserve and sustainably use this biodiversity.*

Target 2
By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems.

- *The conservation and development of rivers as areas of high value biodiversity has been integrated into national and local development and planning processes.*

Target 3

By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socio economic conditions.

- *There are no more incentives, including subsidies from EU or governments, to destruct rivers by hydropower development or other means. All incentives are eliminated, phased out or reformed in order to avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied.*

Target 4

By 2020, at the latest, Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits.

- *Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production of electricity and have kept the impacts of use of natural resources well within safe ecological limits, what clearly excludes the construction of hydropower plants massively impacting freshwater biodiversity.*

Target 5

By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.

- *The loss of all river sections holding self-sustaining Huchen populations has been brought to zero, and degradation and fragmentation is stopped.*

Target 6

By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.

- *All Huchen stocks are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted populations, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.*

Target 11

By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.

- *All river sections holding self-sustaining Huchen populations are conserved through effectively and equitably managed; ecologically representative and well connected systems of protected areas, and integrated into the wider landscapes.*

Target 12

By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.

- *The regional extinction of Huchen and other threatened species has been prevented and their conservation status, particularly of those populations most in decline, has been improved.*

Target 14
By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.

- *River sections holding Huchen populations valuable for ecotourism and recreation are restored and safeguarded, taking into account the needs of local communities, and the poor and vulnerable.*

Target 15
By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

- All former Huchen rivers are assessed for potential restoration as pollution reduction and de-damming in a way, that they can be in a good ecological status and that existing Huchen stocks can expand.

Target 17
By 2015 each Party has developed, adopted as a policy instrument, and has commenced implementing an effective, participatory and updated national biodiversity strategy and action plan.

- *Each government has consequently implemented an effective, participatory and updated national biodiversity strategy and action plan fully recognizing freshwater biodiversity.*

Target 18
By 2020, the traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels.

- *The traditional knowledge, innovations and practices of local communities relevant for the conservation and sustainable use of fish populations and other biodiversity are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected at all relevant levels.*

Target 19
By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied.

- *Knowledge, the science base and technologies relating to river conservation as well as fish conservation are improved, widely shared and transferred, and applied.*

Target 20
By 2020, at the latest, the mobilization of financial resources for effectively implementing the Strategic Plan for Biodiversity 2011-2020 from all sources, and in accordance with the consolidated and agreed process in the Strategy for Resource Mobilization, should increase substantially from the current levels. This target will be subject to changes contingent to resource needs assessments to be developed and reported by Parties.

- *Financial resources for effectively implementing the different conservation activities and protected areas in the river sections identified in this study are mobilized from all sources.*