TÜBİTAK

Turkish Journal of Zoology

http://journals.tubitak.gov.tr/zoology/

Research Article

Turk J Zool
(2019) 43: 215-223
© TÜBİTAK
doi:10.3906/zoo-1711-52

Hucho hucho (Linnaeus, 1758): last natural viable population in the Eastern Carpathians – conservation elements

Angela CURTEAN-BĂNĂDUC[1,*], Saša MARIĆ[2], Guti GÁBOR[3], Alexander DIDENKO[4], Sonia REY PLANELLAS[5], Doru BĂNĂDUC[1,*,]**

[1]"Lucian Blaga" University of Sibiu, Sibiu, Romania
[2]University of Belgrade, Belgrade, Serbia
[3]Danube Research Institute, Budapest, Hungary
[4]Institute of Fisheries, Kiev, Ukraine
[5]School of Natural Sciences, University of Stirling, Stirling, United Kingdom

Received: 30.11.2017 • **Accepted/Published Online:** 18.01.2019 • **Final Version:** 01.03.2019

Abstract: There is great variation in the conservation status of the last habitats with long-term natural viable populations of the salmon species *Hucho hucho* in Maramureş Mountains Nature Park, Eastern Carpathians (Romania). According to the specific guidelines for Natura 2000, 42.11% are in good conservation status, 31.57% are of average status, and 26.32% are in a partially degraded condition. In this study area, 6 main risk elements were identified related to human impact on the environment: poaching, minor riverbed morphodynamic changes, liquid and solid natural flow disruption, habitat fragmentation leading to isolation of fish populations, organic and mining pollution, and destruction of riparian tree and shrub vegetation. All of them have contributed to the decrease of *H. hucho* distribution in the study area to about 50% of the previous local range. Individuals of this species were recorded in only 21 of the 370 sampling stations.

Key words: Danube salmon, Carpathians, habitats, human impact, assessment

1. Introduction

Maramureş Mountains Nature Park is in the north of Romania, in the Eastern Carpathians. Most of its rivers and streams are in the Vişeu basin, with a few in the Bistriţa Aurie basin (Curtean-Bănăduc et al., 2008; Mureşan, 2009).

The high variety of aquatic habitats in the Vişeu basin and their uncommon and endangered species have great conservation value. This includes the fish species, as stated by different naturalists in over a century of ichthyologic research (Bănărescu, 1964; Staicu et al., 1998; Bănăduc et al., 2011). Half of the fish species in the study area are of conservation importance, including *Eudontomyzon danfordi*, *Thymallus thymallus*, *Leuciscus souffia*, *Romanogobio uranoscopus*, *Barbus meridionalis*, *Sabanejewia aurata*, and *Cottus gobio*. Perhaps the most valuable is the iconic, elusive, largest, and most endangered endemic salmon species of Central and East Europe, the Danube salmon or huchen, *H. hucho* (Linnaeus 1758).

H. hucho is covered by European Union Habitats Directive 92/43/EEC (Natura 2000 Code: 1105, Actinopterygii – Salmoniformes – Salmonidae), Romanian Law 13 of 1993, and O.U.G. 57/2007 of the Romanian Government concerning natural preserved areas, natural habitat protection, and wild flora and fauna.

H. hucho was present in the research area in the 19th and 20th centuries (Homei, 1963; Telcean and Bănărescu, 2002; Bănăduc et al., 2013).

Historically, it was widespread across the mountainous areas of the Danube basin, in the Carpathian, Balkan, and Alpine regions, inhabiting mountainous and submountainous reaches of fast-flowing rivers and large streams from the grayling zone to the upper part of the barbel zone. It prefers deeper pools and stretches with a gravel bottom and needs well-oxygenated water at temperatures rarely above 15 °C (Bănărescu, 1964).

The required spawning habitats are on clean gravel substrate in rapid-flowing waters of small upstream tributaries; the spawning season is in March–April at 6–10 °C; the age of males at maturity is 3–4 years and weight is about 1 kg; female maturity is 4–5 years and 2–3 kg. Adults mainly seek prey at night. Juveniles feed on drifting

*These authors contributed equally to this work.
**Correspondence: ad.banaduc@yahoo.com

invertebrates and become predators after 1–3 years (Pintér, 1989).

Under natural conditions, the lotic systems of the Romanian Carpathians are favorable for *H. hucho*, especially in their upper reaches. In the second part of the 19th century and beginning of the 20th century, this species' natural populations inhabited many basins of these mountains: Mureş, Cerna in the Banat region, Danube (via its tributaries), Jiu, Olt, Lotru, Argeş, Râul Târgului, and possibly the Crişul Negru, Crişul Alb, Crişul Repede, Strei, Timiş, Râul Doamnei, Buzău, Moldova, Suceava, and Siret (Antipa, 1909; Bănărescu, 1964). In the middle of the 20th century, natural populations of this species still occurred in the Vişeu, Vaser, Novăţ, Ruscova, Bistriţa Moldovenească, Dorna, Suceava, and Moldova (Bănărescu, 1964; Bănăduc, 2007a, 2007b, 2008a, 2008b, 2011; Bănărescu and Bănăduc, 2007; Bănăduc et al., 2012).

Before its downturn due to anthropogenic impact (Witkowski et al., 2013), *H. hucho* was one of the most popular fish in Romania for sport fishing as well as for food (Băcescu, 1947). Now, however, it is very rare and overfished, in part by illegal fishing, which implies that its protected status is not being respected in some cases.

The principal aim of this research was to test the hypothesis that the connection of the study area with the nearby Tisa River sector (which is in a relatively good state from the ichthyologic point of view) may induce good conservation status of the natural viable population of *H. hucho* in the Eastern Carpathians (Romania). Other aims are to identify the human pressures and threats in the area, and to offer in situ management elements to improve the ecological status of *H. hucho* and increase the chances for this fish species' conservation.

Anthropogenic impact is one of the most important all-encompassing determinants that lead to changes in the structure of fish communities (Lenhardt et al., 2009; Stefanov et al., 2011; Joy, 2014; Halpern et al., 2015; Bănăduc et al., 2016; Gökçe et al., 2016; Monte-Luna, 2016). The anthropogenic factors that can affect identification and mapping of this species on the ground were the basis for in situ management to improve the ecological status of the researched fish species' population.

2. Materials and methods

The research area comprised the Vişeu River basin and tributaries in the Maramureş region (northwestern Romania). This research was conducted between the years 2010 and 2015. The main objectives of this research were to map and assess the conservation status of *H. hucho*, as well as to identify the main factors that could influence the conservation status of this species in the study area. The study area comprised 370 lotic sections (Figure 1); all sections were evaluated for environmental condition, species dispersion, habitat pressure, and presence/absence of an *H. hucho* population. Over 300 km of streams and rivers in the Vişeu River basin were covered by the sampling.

To evaluate the dispersion and condition of *H. hucho* populations, fish samples were taken from about 2–3 km between 2 successive sampling sections along all running waters of the research area. Lotic sections were selected for being adequate potential habitats for one or more life stages of *H. hucho*. To have greater coverage on the ground, additional sampling was done upstream from the last appropriate habitats for this fish species. This choice of sampling sections was built on experience and knowledge obtained in the field by the authors during over 20 years in the research area; it is representative of the information obtained and allows evaluation of the effects of biotope characteristic alterations, hydrotechnical works, substratum exploitation, illegal fishing, presence of pollution sources, etc. on the research population.

Quantitative fishing measured by catch per unit effort (CPUE) was done by electrofishing. Five 1-km sections were explored for an interval of 3 h on the Vişeu River and for 2 h on the tributaries. After *H. hucho* was sampled (red bullets in Figure 2; Table), the fish were released back into their aquatic habitat.

The CPUE was converted based on correspondence to these categories: (C) – common species, (R) – rare species, or (V) – very rare species, in agreement with the Natura 2000 standard data form guidelines.

We based our classification on the Natura 2000 guidelines with the criteria "conservation degree of specific habitats" on the standard data forms, which include 2 subcriteria: i) degree of conservation of habitat features that are essential for the species and ii) recovery potential.

Criterion i) requires an all-encompassing assessment of habitat characteristics concerning the requirements of *H. hucho*. "The best expertise" way was used to rank this criterion in elements: I, in excellent condition; II, well preserved; III, in partly degraded condition.

When subclass I is assigned "I, elements in excellent condition" or "II, well-preserved elements," criterion B (b) should be classified entirely as "A: excellent conservation" or "B: good conservation", regardless of the other subcriterion classification. For subcriterion ii), which was used only if the items were partly degraded, an assessment of the viability of the studied population is essential. The acquired ranking system is: I, easy recovery; II, potential restoration with moderate effort; III, restoration is challenging or impossible.

The synthesis used for categorization relies on the following subcriteria: A, excellent conservation = excellent condition; B, good conservation = well-preserved elements; C, average or reduced conservation = all other mixtures.

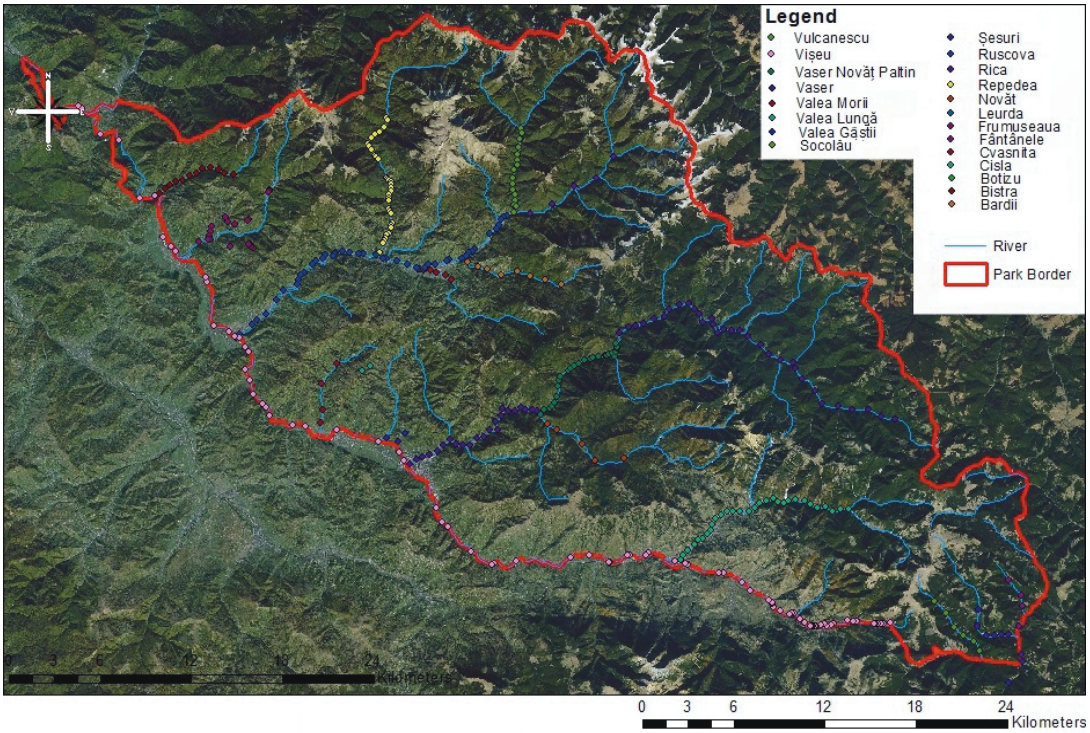

Figure 1. Location of the 370 sampling stations in the nature park.

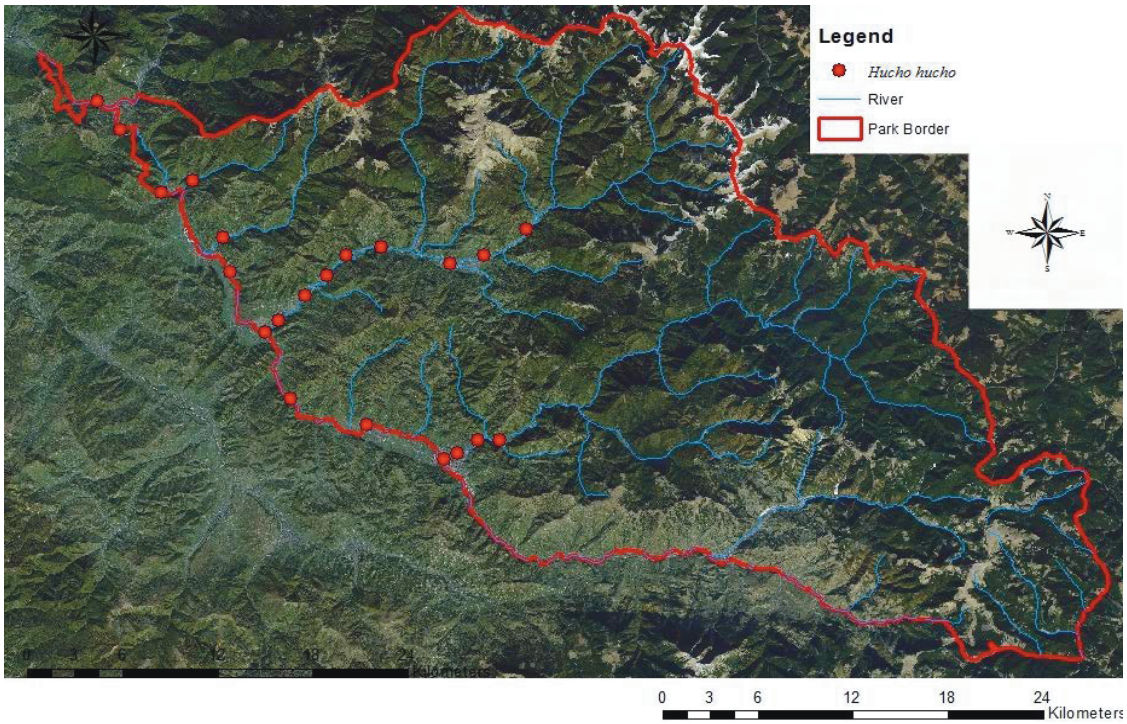

Figure 2. *H. hucho* capture locations.

Table. *H. hucho* sampling sites and sampling individual numbers and length in Maramureș Mountains Nature Park.

River	Station	Latitude, N	Longitude, E	Catch index number of individuals per time unit (3 h in Vișeu River and 2 h in Vișeu tributaries); length of individuals (cm)	Characteristic habitat state
Vișeu	53	47°43′25.9″	24°23′54.6″	1 (15 cm)	Reduced
Vișeu	55	47°43′54.8″	24°20′04.9″	1 (19 cm)	Reduced
Vișeu	61	47°45′32.2″	24°17′06.4″	1 (13 cm)	Reduced
Vișeu	69	47°48′56.3″	24°14′50.8″	1 (22 cm)	Reduced
Vișeu	74	47°51′54.0″	24°12′02.6″	2 (18 cm; 11 cm)	Average
Vișeu	76	47°53′45.7″	24°10′05.9″	3 (66 cm; 19 cm, 17 cm)	Good
Vișeu	79	47°55′01.1″	24°07′56.1″	1 (54 cm)	Reduced
Ruscova	4	47°50′50.8″	24°30′02.7″	1 (9 cm)	Reduced
Ruscova	10	47°49′46.8″	24°28′12.5″	1 (7 cm)	Reduced
Ruscova	16	47°49′24.5″	24°26′02.9″	1 (11 cm)	Reduced
Ruscova	22	47°49′46.5″	24°24′05.6″	2 (11 cm; 9 cm)	Average
Ruscova	30	47°49′50.7″	24°21′25.3″	1 (13 cm)	Reduced
Ruscova	35	47°49′16.1″	24°19′57.1″	2 (12 cm; 19 cm)	Average
Ruscova	38	47°48′52.6″	24°19′34.6″	2 (17 cm; 16 cm)	Average
Ruscova	42	47°47′36.3″	24°17′25.3″	1 (17 cm)	Reduced
Vaser	44	47°43′32.3″	24°29′03.6″	1 (21 cm)	Reduced
Vaser	47	47°43′19.7″	24°27′58.7″	1 (15 cm)	Reduced
Vaser	51	47°42′57.1″	24°26′36.1″	2 (14 cm; 9 cm)	Average
Vaser	53	47°42′46.7″	24°25′56.4″	1 (23 cm)	Reduced

3. Results

The Table shows the lotic sectors where this predatory fish species was found during the research period, with a minimum of one individual and a maximum of 3 individuals. Also shown is the total body length of the individuals, including juveniles and sexually mature adults, allowing for local reproduction. The CPUE reveals that *H. hucho* is mostly a rare to very rare species in the studied area.

In the Vișeu basin, the *H. hucho* population status can be considered as reduced based on the following criteria: distribution of fish individuals by age classes, fish population size, fish distribution area size, and relative percentage of individuals of the studied fish species in the structure of fish associations.

Within the research area, *H. hucho* formed permanent populations in 4 basins and subbasins: the Tisa River, including the confluence area with the Vișeu River; the Vișeu River, middle and lower sectors; the Vaser River, middle and lower sectors; and the Frumușeaua River, lower sectors. The habitats of *H. hucho* are large enough in the area of interest, but their present condition is generally low to moderate, and only rarely good (Table); this offers potential for the continuity and sustainability of *H. hucho* populations in the research area.

Human-impact pressures found in the studied basins and subbasins have a medium to significant effect on fish fauna, also affecting the long-term sustainability of the *H. hucho* species.

Based on the studied sampling of lotic sections and regarding the abovementioned impact categories, we found 42.11% of the studied lotic sectors (in the Vișeu and Vaser) to be of good conservation status for the *H. hucho* species, 31.57% (in the Vișeu and Vaser) of medium conservation status where restoration is still possible, and 26.32% (in the Vișeu and Ruscova) in a degraded condition where long-term restoration would be difficult. The Ruscova Stream is in the worst condition from the perspective of *H. hucho* conservation, with the lowest presence values.

Based on the fieldwork results, some risk elements (pressures and threats) related to the biological and ecological requirements of *H. hucho* were identified: poaching, minor changes in riverbed morphodynamics, disruption of natural water flow and sediment transport, fragmentation of habitats and of fish populations,

pollution (primarily correlated with pollution from mining, plus organic pollution), and destruction of riparian vegetation.

3.1. Poaching

Throughout the fieldwork, both day and night illegal fishing activities using handmade electrofishing equipment (vehicle accumulators and batteries) were observed during more than 20% of our fieldwork period. In other instances, poachers were observed carrying out illegal fishing using a relatively large variety of substances to poison fish. The questioning of 431 local people suggests that illegal fishing activities are common in the Vişeu basin; illegal fishing is one of the main causes of the reduction in abundance of *H. hucho*.

Illegal fishing is one of the most important factors that have induced a severe downturn of *H. hucho* populations in some Danubian countries (Virban and Ionescu, 2011). This species is also valued by poachers in the Ukrainian section of the Tisa River and its tributaries; it sometimes becomes a target during the spring period, when it can be easily caught in spawning grounds by spearing (Didenko et al., 2014). In spite of its conservation status, *H. hucho* is also caught by anglers. However, fish that migrate from the Vişeu River to the Tisa River for the winter can find refuge there. This is because a significant part of the Tisa River flows within the Romanian–Ukrainian border zone, where human access is rather limited.

3.2. Minor changes in riverbed morphodynamics due to river engineering

H. hucho is a migratory fish and it has relatively varied habitat needs in different periods of its lifecycle, including diverse natural processes of riverbed morphology. Dykes, sills, dams, roads in riverbeds, gravel excavation, sediment transport modification, etc. have had a significant impact on the long-term natural morphodynamics of the riverbeds. Therefore, all key habitats for the lifecycle periods of the species have been negatively affected by these human interventions, which has brought about the decline in population.

3.3. Disruption of water flow and natural sediment transport

The interruption of the natural flow of water and sediment required for creation and persistence of key habitats for *H. hucho* may also bring about the decline of populations. Increased water turbidity due to forestry activities managed without sufficient supervision is only one example of the factors interrupting natural sediment transport in the studied lotic systems.

3.4. Habitat fragmentation and isolation of populations

Habitat fragmentation and population isolation create trends toward genetic isolation, decline in genetic variability, and sometimes inbreeding and/or extinction. Obstacles breaking rivers into sectors—a main cause of habitat degradation—can limit *H. hucho* access to ancient spawning areas, producing decreased abundance and sometimes its loss (Holčik, 1990). An example is the Tereble-Ritska hydroelectric power station built on the Rika River (Transcarpathia, Ukraine) in 1949–1956. It cut off about 30 km of the river where *H. hucho* had historically run for spawning. Dams can also have collateral effects on *H. hucho* populations by causing alterations in water temperature, modifying water flow, obstructing transport of inorganic and organic substances, and collecting sediment (Witkowski et al., 2013).

3.5. Organic pollution

The organic pollution from waste discharge, fish farms, and agriculture has contributed to the rapid decline and sometimes local and/or regional disappearance of *H. hucho* from its known historical spawning areas (Jungwirth, 1978). A long-term source of constant environmental stress for this valuable fish species is the continuous problem of sewage and wastewater treatment, as well as pollution from farm runoff, in the majority of the Vişeu basin (especially on the Vişeu River itself). Efficient, complete sewage systems must be implemented in this basin, and waste liquids from riverine towns and villages should be processed and cleaned.

3.6. Pollution caused by mining activities

Pollution produced by heavy metal mining in the Ţâşla basin (incidents of which have been recorded) has negatively affected not only the Ţâşla River but also the upstream Vişeu River habitats (Jelea et al., 2007). The influence of precipitates from mine galleries and refuse heaps is considered to be major in the Ţâşla basin and significant in the upstream Vişeu.

4. Discussion

By the end of the 20th century, long-term viable natural populations of *H. hucho* were no longer found by the authors of this research in the Eastern Carpathians of Romania, except in the Vişeu and Tisa basins area. These populations persist in the Vişeu River basin because of the hydrographical free connection of this remote northern Romanian basin with the nearby Tisa River sector, which is in a relatively good state from the ecological point of view (Bănăduc et al., 2011). The state of typical *H. hucho* habitats in the Maramureş Mountains Nature Park spans all categories, varying greatly from mostly bad to average, and more rarely to good in different areas. The connectivity of the major lotic systems and proper, optimally adapted in situ management measures could therefore play a vital role in preventing this extraordinarily valuable fish species from further decrease in its native range. We suggest a set of site-specific recommendations for protecting *H. hucho* in the research area to overcome the identified pressures and threats.

In this research, the main identified human impacts in the Maramureş Mountains Nature Park that have resulted in the deterioration of river and stream habitat conditions in the study area are illegal fishing, disruption of natural flow and sediment transport processes, minor changes in riverbed morphodynamics, habitat fragmentation and the isolation of some fish populations, organic pollution, pollution caused by mining, and destruction of riparian tree and shrub vegetation.

Some main minimal management elements should be put into action to address these impacts, including the control of illegal fishing; creation of buffer zones on lotic systems and habitat restoration where necessary; basinwide coordination of water use over time and space; regulation of sewage, wastewater, and surface water pollution; readjustment of hydropower use of lotic habitats; application of integrated water resource management for the watershed; building and authorization of ecological site networks; restoration of stream and river connectivity; support for high-quality scientific inventories and integrated management-oriented research; more scientific information-based decision making; stocking and restocking as a tool for the conservation and restoration of *H. hucho* populations; and strict regulation of hydropower facilities.

All of the identified human impact categories (Figures 3 and 4) have contributed to the decrease of *H. hucho* species distribution (Figure 2) in the Maramureş Mountains Nature Park study area within the last century. It has been reduced to about 50% of its previous local natural range as revealed in the past by Bănărescu (1964). Due to the identified human impacts, *H. hucho* can currently be considered as a relatively rare fish species in the research area.

Cross-border management is needed. Despite the fact that *H. hucho* is not a very abundant species, it is nevertheless quite widespread in the Transcarpathian region, including the Tisa River, and it maintains self-sustainable populations (Didenko et al., 2018). In the Tisa River, this species occurs from the Hungarian–Ukrainian border, along the Romanian–Ukrainian border to Rakhiv, and further upstream in the Chorna Tisa River (Velykopolsky, 2010). The Tisa River provides major wintering grounds for this fish species and can be a refuge during periods of low water levels in the Tisa tributaries, where major spawning grounds of *H. hucho* are located (Teresva, Rika, Borzhava, Shopurka, Vişeu, Vaser, Ruscova). Due to the fact that *H. hucho* populations of the Vişeu and Tisa are interconnected and relationships with populations from other Tisa tributaries on the Ukrainian side may exist as well, joint measures aimed at the preservation of this fish species should be implemented by both Romania/EU and Ukraine within the remit of transboundary cooperation programs. It will also be important to investigate the rela-

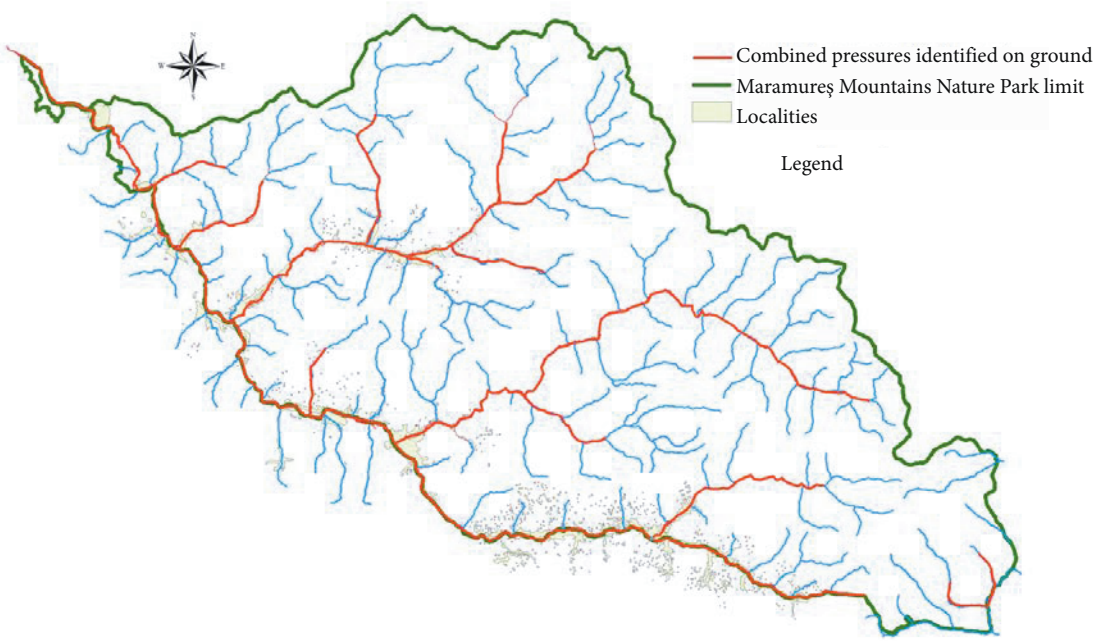

Figure 3. In red, identified combined pressures and threats for *H. hucho* in Vişeu watershed: poaching, changes in minor riverbed morphodynamics, disruption of natural flow and sediment transport, destruction of riparian tree and shrub vegetation, habitat fragmentation and fish population isolation, mining pollution.

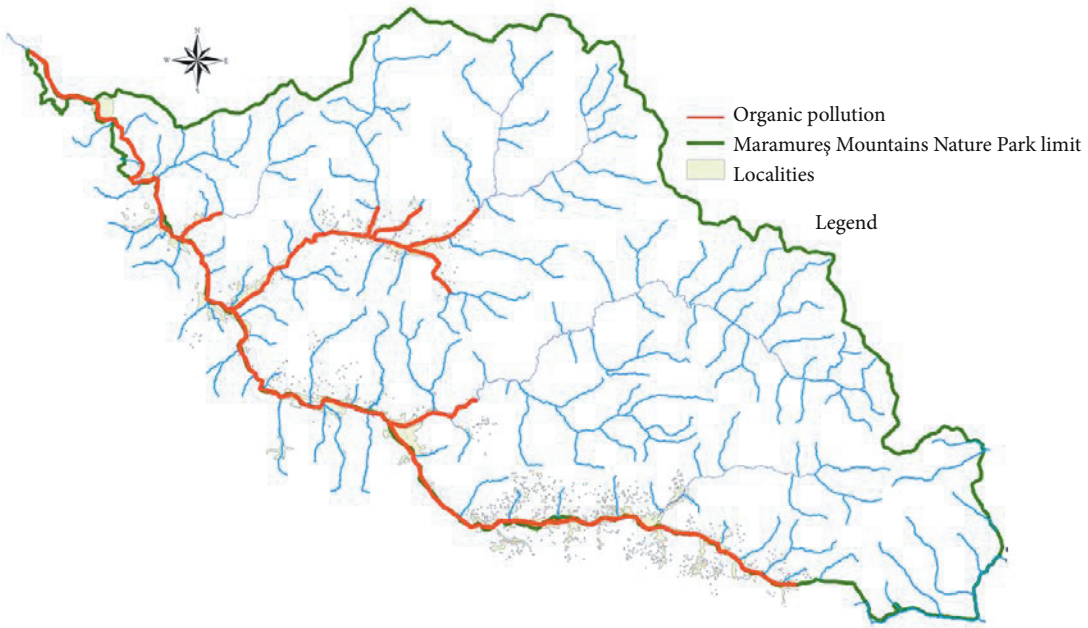

Figure 4. In red, lotic sectors negatively influenced by organic pollution.

tionships between the Romanian and Ukrainian *H. hucho* populations using molecular, genetic, and tracking-appropriate methods.

Enhanced Maramureș Mountains Nature Park management is needed. To address illegal fishing, we suggest the reinforcement of park administration management tools and positive effects through developing and expanding the activities of rangers in the field in order to curtail illegal fishing actions. It is indisputable that more centralized national and/or regional institutions and organizations are not able to control the existing poaching activities. The development of a volunteer entity could also be a solution for this situation, whereby the volunteers would have professional expertise in discerning fish biology and ecology in natural habitats. Equipped with these skills, the volunteers would be able to support rangers in identifying poaching activity.

Basin-wide coordination of river engineering and extraction activities is required. The natural water flow and sediment transport processes of the Maramureș Mountains Nature Park can be preserved as close to the natural state as possible, but this will only be possible if forestry activities and/or riverbed gravel exploitation are not permitted to negatively affect the self-sustainability of the basin.

Furthermore, river engineering works (dykes, dams, bottom sills, micro hydropower plants, mineral exploitations, water extraction, etc.), while advantageous from an economic point of view, should not be permitted by the local park administration without appropriate professional knowledge concerning the effect on *H. hucho*.

The self-sustaining condition of the local park can be managed by regulating extraction and other anthropogenic activities through matching the likely outcome of these activities (e.g., accentuated turbidity) with the likely natural conditions associated with different seasons and timeframes. Any actual or future planned works on the lotic systems in the research area should be subject to management involvement. For example, the impacts of meteoric water washing through mine areas (Staicu et al., 1998) can be made smaller by isolating the mine galleries and by insulating (not just superficially greening) the refuse heaps in the Țâșla basin. Embankments, dams, fords, water extraction, bank modifications, alterations by exploitation of minerals from the riverbed, etc. should not be permitted by the local park administration without the agreement of experts studying *H. hucho*, based on the corroboration of the identified local stress factors and the biological and ecological needs of the species. For example, consideration of the habitat needs of the species would indicate that in dry seasons, when shallow water is common, no ford should be deeper than 10–15 cm.

Bankside activities are the main aspects to consider; the authors suggest that it is important that forestry extraction activities such as the dragging and storage of timber through and in aquatic habitats should be closely observed and linked to forestry regulations, along with close observation of the development of works for lumber storage and exploitation terraces and the required need for reforestation. In this situation, it is recommended to rotate exploitation activities in the subbasins of the Vișeu basin.

The unrestrained upstream–downstream dislocation of habitat areas, including in the various subbasins of the Vişeu basin, is also an important consideration for *H. hucho* guardianship. We recommend researching potential investments in the aquatic habitats very cautiously, as some of them could reduce the upstream–downstream connectedness of the lotic ecosystems, not only by creating diverse crosswise barriers in the riverbed, but also by diminishing water flow or even causing water deprivation in some sectors.

Destruction of riparian tree and shrub vegetation can also cause a loss of riverine plants. Subsequent reduced microclimate protection and reduced trophic resources can also bring about a numerical reduction in fish fauna. To preserve a favorable habitat, ligneous riparian vegetation must be as undamaged as possible for a minimum of 5–10 m width in the upper part of rivers and 10–25 m in their lower part (Curtean-Bănăduc et al., 2014).

In conclusion, the effects of human impacts (Figures 3 and 4) influence many lotic sectors, and unfortunately the score for *H. hucho* in the area of interest is relatively low. This study tried to fill in gaps from similar research, where the results cannot be easily used by regional conservation management stakeholders due to a gap between an academic research approach and the ground-level action desperately needed to support populations of *H. hucho*. The authors suggest some direct and urgent activities to implement in the field rather than taking a more or less "pure" theoretical approach, without which *H. hucho* will continue to vanish from its native range.

Acknowledgments

All data were obtained in the research project "Inventory, mapping, and assessment of the conservation status of fish species of Munţii Maramureşului Nature Park (ROSCI 0124 Maramureşului Mountains)". Special thanks for the continuous support of the Parcul Natural Munţii Maramureşului Administration and Scientific Council members, especially C Bogdan, C Bucur, S Szabo, A Brener, and M Mărginean. Thanks to B Taylor for urging this paper's authors to persist in this research, as shining a light on the situation of the Danube salmon is vital to its conservation.

References

Antipa G (1909). Fauna ichtiologică a României. Bucharest, Romania: Publ. Fond Adamachi (in Romanian).

Băcescu MC (1947). Peştii aşa cum îi vede ţăranul pescar roman: studiu etnozoologic, zoogeografic şi bioeconomic. Bucuresti, Romania: Institutul de Cercetări Piscicole, Imprimeria Naţională (in Romanian).

Bănăduc D (2007a). Fish of Natura 2000 network interest in Romania. In: Alexiu V, Bănăduc D, Benedeke A, Curtean-Bănăduc A, Florescu F, Bell A, Florescu B, editors. Romanian NATURA 2000 NGO Coalition: Contribution for the SCIs Designation. Sibiu, Romania: Alma Mater.

Bănăduc D (2007b). Specii de peşti dulcicoli *şi* migratori *în* mediul dulcicol, prezente *în* România. In: Bănăduc D, Curtean-Bănăduc A, Drăgulescu C, editors. Natura 2000 în România: Conservarea speciilor şi habitatelor acvatice. Sibiu, Romania: Alma Mater, pp. 72-81 (in Romanian).

Bănăduc D (2008a). Socolău River Basin (Vişeu Watershed) Ichthyofauna, Maramureş Mountains Nature Park (Maramureş Romania). Acta Mus Maram 8: 498-506.

Bănăduc D (2008b). The *Hucho hucho* (Linnaeus, 1758) species monitoring in the Vişeu River (Maramureş, Romania). Transylv Rev Syst Ecol Res 5: 183-188.

Bănăduc D (2011). New SCIs proposal regarding the ichthyofauna after the Alpine Biogeographic Seminar for Romania, June 2008. Acta Oecol Carpat 4: 199-208.

Bănăduc D, Oprean L, Bogdan A, Curtean-Bănăduc A (2012). The assessment, monitoring, management of Carpathian rivers fish diversity. Manag Sust Dev 4: 19-27.

Bănăduc D, Prots B, Curtean-Bănăduc A (2011). The Upper Tisa River Basin. Transylv Rev Syst Ecol Res 11: 204.

Bănăduc D, Răchită R, Curtean-Bănăduc A, Gheorghe L (2013). The species *Hucho hucho* (Linnaeus, 1758), (Salmoniformes, Salmonidae) in Ruscova River (Northern Romanian Carpathians). Acta Oecol Carpat 6: 149-166.

Bănăduc D, Rey S Trichkova T, Lenhardt M, Curtean-Bănăduc D (2016). The Lower Danube River-Danube River-Danube Delta-North West Black Sea: a pivotal area of major interest for the past, present and future of its fish fauna – A short review. Sci Total Environ 545-546: 137-151.

Bănărescu PM (1964). Fauna R. P. Române, Pisces-Osteichthyes, XIII. Bucharest, Romania: Academiei Române (in Romanian).

Bănărescu PM, Bănăduc D (2007). Habitats Directive (92/43/EEC): fish species (Osteichthyes) on the Romanian Territory. Acta Ichtiol Roman 2: 43-78.

Curtean-Bănăduc A, Bănăduc D, Sîrbu I. (2008). The Maramureş Mountains Nature Park. Transylv Rev Syst Ecol Res 5: 222.

Curtean-Bănăduc A, Schneider-Binder E, Bănăduc D (2014). The importance of the riverine ligneous vegetation for the Danube Basin lotic ecosystems. In: Cianfaglione K. L'importanza degli Alberi e del Bosco: Cultura, scienza e coscienza del territorio. Trento, Italy: TEMI, pp. 187-210 (in Italian).

Del Monte-Luna P, Lluch-Cota D, Arreguín-Sánchez F, Lluch-Cota S, Villalobos-Ortiz H (2016). Approaching the potential of world marine fish. Transylv Rev Syst Ecol Res 18: 45-56.

Didenko A, Velykopolsky I, Chuklin A (2014). Use of poacher's catches for studying fish fauna in the water bodies of the Transcarpathian region. Transylv Rev Syst Ecol Res 16: 107-116.

Didenko AV, Talabishka EM, Velykopolsky II, Kurtyak FF, Kucheruk AI (2018). Current distribution of the European grayling, *Thymallus thymallus*, and huchen, *Hucho hucho*, in the Transcarpathian region of Ukraine. Vest Zool 52: 65-74.

Gökçe G, İsmet S, Eryaşar AR (2016). Catch composition of trawl fisheries in Mersin Bay with emphasis on biodiversity. Turk J Zool 40: 522-533.

Halpern BS, Frazier M, Potapenko J, Casey KS, Koening K, Longo C, Lowndes S, Rockwood RC, Seling ER, Selkoe KA et al. (2015). Spatial and temporal changes in cumulative human impacts on the world's ocean. Nat Comm 6: 7615.

Holčik J (1990). Conservation of the huchen, *Hucho hucho* (L.), (Salmonidae) with special reference to Slovakian rivers. J Fish Biol 37A: 113-121.

Homei V (1963). Fauna ihtiologică a râului Vişeu şi importanţa ocrotirii ei. Ocrot Nat 7: 129-144 (in Romanian).

Jelea M, Koovacs ZM, Jelea SG, Gheţa DE (2007). Research concerning the evolution of the phenomena of acid mining drainage in the settling pond of the flotation tailings from Tăuţii de Sus (Maramureş). Environ Prog 11: 252-256.

Joy MK (2014). Freshwaters in New Zealand. In: Stow A, Maclean N, Holwell G, editors. Austral Ark: The State of Wildlife in Australia and New Zealand. Cambridge, UK: Cambridge University Press, pp. 227-239.

Jungwirth M (1978). Some notes to the farming and conservation of the Danube salmon (*Hucho hucho*). Environmental Biology of Fishes 3: 231-234.

Lenhardt M, Markovic G, Gacic Z (2009). Decline in the index of biotic integrity of the fish assemblage as a response to reservoir aging. Water Resources Management 23: 1713-1723.

Mureşan A (2009). Relationship between the bed material size and the amount of metamorphic and volcanic rocks in hydrographic basins regarding two rivers from Maramureş Mountains. J Earth Environ Sci 4: 12009.

Pintér K (1989). Magyarország halai. Budapest, Hungary: Akadémiai Kiadó (in Hungarian).

Staicu G, Bănăduc D, Găldean N (1998). The structure of some benthic macroinvertebrates and fishes communities in the Vişeu Watershed, Maramureş, Romania. Trav Mus Natl Hist Nat Grigore Antipa, Bucureşti 40: 587-608.

Stefanov T, Trichkova T, Sivkov Y (2011). Threatened fish species. In: Golemansky V, Peev D, Biserkov V, editors. Red Data Book of the Republic of Bulgaria, Vol. 2, Animals. Sofia, Bulgaria: Bulgarian Academy of Sciences, pp. 1-372.

Telcean I, Bănărescu PM (2002). Modifications of the fish fauna in the upper Tisa River and its southern and eastern tributaries. Tiscia Mon Ser 6: 179-186.

Velykopolsky I (2010). Distribution of Danube salmon (*Hucho hucho*) in the Tisa River basin. In Proceedings of the International Conference on Reproduction of Natural Populations Of Valuable Fish Species, 20–22 April 2010, St. Petersburg, Russia, pp. 36-37.

Virban I, Ionescu O (2011). Study on Danube salmon populations (*Hucho hucho* L.) of Romania. In: Biennial International Symposium, Forest and Sustainable Development. 15–16 October 2010, Braşov, Romania, pp. 373-380.

Witkowski A, Bajic A, Treer T, Hegedis A, Maric S, Sprem N, Piria M, Kapusta A (2013). Past and present of and perspectives for the Danube huchen, *Hucho hucho* (L.), in the Danube basin. Arch Pol Fish 21: 129-142.