COŞTEI HYDROGRAPHIC DIVERSION NODE, A HISTORICAL ENVIRONMENT QUALITY AND BIOLOGICAL RESOURCES ACCESSIBILITY GAME CHANGER; ANTHROPOGENIC INDUCED PROBLEMS AND SUSTAINABLE SOLUTIONS – AN ICHTHYOLOGIC PERSPECTIVE

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KEYWORDS: lotic system, hydrotechnical diversion work, habitat change, biological/fish resources loss, bio-eco-economy, sustainable connectivity reconstruction.

ABSTRACT

26 fish species were affected by the Coştei historical diversion hydrotechnical system build in 1758. In order to mitigate the negative effects produced by this hydrotechnical work on the fish, a migration system, of nature-like meandering by pass type was proposed. The dimensions of this channel and the slope of about 2% allow fish, and other aquatic organisms to move upstream and downstream of the spillway.

RÉSUMÉ: Le nœud de dérivation hydrographique de Coştei, une qualité historique de l'environnement et l'accessibilité aux ressources biologiques changent la donne; problèmes anthropiques induits et solutions durables – une perspective ichtyologique.

26 espèces de poissons ont été affectées par le Coştei système hydrotechnique de dérivation historique construit en 1758. Afin d'atténuer les effets négatifs produits par ces travaux hydrotechniques sur les poissons, un système de migration, de méandres par type de passe, de nature similaire a été proposé. Les dimensions de ce chenal et la pente d'environ 2% permettent aux poissons et à d'autres organismes aquatiques de se déplacer en amont et en aval du déversoir.

REZUMAT: Nodul hidrografic deversor Coştei, un modificator istoric al calităţii mediului şi a accesibilităţii resurselor biologice; probleme induse antropic şi soluţii durabile – o perspectivă ihtiologică.

26 specii de peşti au fost afectate de nodul hidrotehnic deversor Coştei construit în 1758. Pentru a atenua efectele negative produse de această lucrare hidrotehnică asupra peştilor, s-a propus un sistem de migraţie, de tip by pass meandrat. Dimensiunile acestui canal şi panta de aproximativ 2% permit peştilor şi altor organisme acvatice să se deplaseze în amonte şi în aval de deversor.

INTRODUCTION

Over one billion of people are suffering by hunger and over one billion by malnutrition, the accessibility to animal and especially high quality animal protein (i.e. fish protein) being one of the key problem (Bănăduc et al., 2012a). The bio-economy and eco-economy aim to combat the fish protein scarcity (Bănăduc et al., 2012b). There are many causes with important global effects that reveal the decision makers the value of sustainable development as a foundation for bio-eco-economy, based on science which offers solutions for a wise use of natural resources and services, and avoid and/or diminish the local, regional, and global ecological potential support overshoot. Among these causes are: the last economic crisis that shook all national economies and international capital markets (Lane, 2010; Porfirev, 2010); inflation that affects even efficient and stable economies (Campbel et al., 2009; Che et al. 2011), accelerated and continuous growth of the human population (Bongaarts, 2009; Lutz, 2011), migration dynamics (Debra, 2001; Solano-Garcia, 2009), the decreasing level of education (Mok, 2010), unsatisfactory health of human population (Morris, 2009; Samir, 2009), the occurrence at irregular intervals of natural and/or anthropogenic induced disasters (Berger, 2010; Land, 2010), deterioration of the qualitative and quantitative characteristics of some ecological support systems and of the resources and/or services offered by them to the human society (Curtean-Bănăduc et al., 2007), the need for biofuels (Bogdan et al., 2010), hunger or high food prices in some parts of the world (Maneschi et al., 1997; Brinkman et al., 2010), climate changes and disruption (Boston and Lempp, 2011; Tamura, 2011), biodiversity loss and the sixth mass extinction (Barnosky et al., 2011; Bradshaw et al., 2021), the security level decreasing and negative economic effects induced by the actions of terrorist entities that are hostile to the currently international status quo (Pan et al., 2009; Sela-Shayovitz, 2010), political impotence (Hejny, 2018; *, 2018), etc.

Water as one of the most essential natural resources and habitat is not only an “elementary” fundamental source for life on Earth, but also has an essential importance on the environmental, economic, and social equilibrium and development of the world (Falkenmark, 2020; Zhang et al., 2021). Water natural resources are the most exceedingly important element of the environment liable for the development of human civilization (Juuti et al., 2007; Cianfaglione, 2018), for sustainable development (Unesco Water, 2006; Oprean, 2012), and turn into a vital issue in the present climate change reality (Şahin et al., 2020), and other global changes (Cianfaglione, 2014; Gulbenkian Think Tank, 2014). The water quantity and quality of freshwater systems, descending resources, is turning into a significant problem for almost two-thirds of the all-encompassing human population; almost all the regional scale water basin faces serious water quality and quantity issues and their corresponding resources insufficiency or/and inadequacy (Abu-Zeid and Shiklomanov, 2004; Mekonnen and Hoekstra, 2016). Freshwater systems in spite of their importance, in this regard, have declined more rapidly than marine habitats (Sala et al., 2000). Even though enclosing barely 0.8% of our planet surface, fresh waters have one-third of the named vertebrate species and 9.5% of the known animal species, and around 50% of all fish species (Joy et al., 2019). The health of lotic aquatic ecosystems degraded physically, chemically, and biologically due to wide variety of threats (climate change, pollution, water abstraction, river channelization, damming). Lotic systems are among the most degraded ecosystems of the Earth (Vörösmarty et al., 2010).

The most diverse lotic systems’ on earth are highly threatened due to river fragmentation (Bosshard, 2015). A serious threat that influences aquatic communities is longitudinal fragmentation (Birk et al., 2012). For example, the building of regulators, dams, and weirs for various purposes (e.g., municipal water supply, flood control, irrigation, hydropower, navigation) change water temperature, movement of water and sediment, and exchange of nutrients, which adversely impact the environmental flow requirements (Acreman and Dunbar, 2004) and, afterward, hamper fish populations and other aquatic organisms (Soolutayo, 2012; Olopade, 2013; Rumana et al., 2015). In the present anthrophosphere, the water, the aquatic and semi-aquatic habitats and associated non-living and living elements are considered and treated as resources, being overused, reshaped, and changed by humans (Barinova and Krassilov, 2012; Del Monte-Luna et al., 2016; Sender et al., 2017; Lemenkova 2020). Recognizing the progressing habitat fragmentation worldwide, research put effort into conservation measures for restoring connectivity of riverine habitats (Branco et al., 2014).

In the last decade, some improvement has been made in recover the rivers and streams longitudinal connectivity by implementing ecological principles including in the studied Carpathian Basin area (Voicu and Voicu, 2014, 2015; Bănăduc et al., 2020a; Voicu et al., 2020). Although, there are some local solutions for restoring longitudinal connectivity in the Timiş Basin (Curtean-Bănăduc et al., 2018), remains one of the unresolved challenge of completely restoring this connectivity due to the attenuation of hydromorphological pressures generated by transversal hydrotechnical works, not only in the Timiş River basin but worldwide (Fuller et al., 2015). Based on the European Water Framework Directive, the ecological capabilities of bypass canals is an urgent need for ecological improvement of rivers (Pander, 2013). Creating an alternative depth bypass increases the efficiency of the bypass compared to the existing surface bypass (Knott et al., 2019).

The Danube River's 801,093 km^2 basin, to which the Timiş Basin belongs, is not a different case, the most ancient known human footprint date since 180.000 B.C., being one of the most relevant European watersheds from the points of view of its natural environment, history, culture, and economic value (Liepolt, 1967; Tockner et al., 2009; Bănăduc et al., 2016). The Danube basin is adversely influenced by a diversity of human-made impact effects: habitats fragmentation and isolation (Popa et al., 2019); ecosystem degradation (Popa et al., 2016); water, sediments, and fish pollution (Bănăduc et al., 2011; Curtean-Bănăduc et al., 2020b); decreasing fisheries production of economically fish species and hybridization (Popa et al., 2017); riverine land exploitation (Curtean-Bănăduc et al., 2007); riverine ecotone degradation (Curtean-Bănăduc et al., 2019); disruption of water and sediment flow (Curtean-Bănăduc et al., 2018); with increasing negative effects due to climate change (Bănăduc et al., 2020b), all of these bringing in light the need for special management measures for the Danube River basin (Bloesch et al., 2012; Bănăduc et al., 2021). Past and present anthropogenic environmental stress reflects the high susceptibility of natural freshwater ecosystems in the lower Danube basin too (Iordache et al., 2020). As a part of the Danube middle-lower basin, the Timiş River has fluvial related characteristics (stream networks types, hydro-geomorphologic structures, elevation, landforms, etc.) which were from ancient time determinant attractants for constructions and human settlements (Petrescu and Hosu, 2020).

The historical human pressures that have a negative impact on the Timiş River basin are hydro-technical works, water accumulations, settlement works and construction of dikes and banks defence, agricultural and industrial development, and urbanization (Burghelea et al., 2013). Between 1728 and 1732, a significant part of the river Bega course was regularized, creating in its lower sector a 115 km navigable canal to support the Timișoara (the capital of Banat Region) growing economy. Thus, the city was connected, via the river Tisza and the Danube, to the Central European rivers and the Black Sea, becoming able to cope with mass transport before the advent of the railway. Therefore, the regularization of the Bega and Timiș courses changed the image of the city and surrounding area into a shining prosperous one.

Coştei hydrotechnical node is a diversion system located (45º44'10.88"N – 21º51'3.83") at the branch of the Timiş-Bega discharge channel from the Timiş River, in the west of Romania (Fig. 1). A dam house (Fig. 2) has been placed on this canal which aims to control the flow of water which is directed towards the Bega River/Canal (Fig. 3).

Figure 1: Coştei hydrotechnical diversion system area.

Figure 2: The flow of water control dam house.

Figure 3: The Bega River/Canal downstream the Coştei dam house.

This hydrotechnical node was built in 1758. Its purpose was and still is to continuously direct the waters of the Timiş River in Bega Canal especially during times of drought to maintain a significant higher and constant flow of water in the Bega River. Over 10,000 years old human settlement, energetic, complex, and continuous socio-economic development of Timişoara, the third biggest present Romanian city which maybe not by chance takes the name of Timiş River instead of Bega River which crosses it, and its metropolitan area with a total of over a million people in present, and the vast agriculture surroundings which need irrigations, create a continuous increasing thirst of a higher amount of water, downstream Coştei diversion system the Timiş River becoming much, much scarcer in water along history downstream Coştei River (Figs. 4-6).

Figure 4: Timiş River upstream the Coştei hydrotechnical diversion system.

This hydrotechnical node is composed of a spillway dam with an upper length of 877 m, width 127, and a height of 10.5 m, (Fig. 5) located on the Timiş River and Bega Canal (Fig. 3) that starts from Timiş upstream of the spillway dam.

Figure 5: Coştei Dam on Timiş River; no water was left to flow over the dam.

Figure 6: Timiş riverbed with scarce water flow downstream the Coştei Dam.

The Coştei Dam is an overflow dam with a wide threshold of boulders in wooden houses filled with raw stone. To avoid floods in Timişoara, another hydrotechnical system at Topolovățu Mic, during periods of high water, directs the excess flow recorded by Bega River back in the Timiş River. The Coştei and Topolovăţu Mic hydrotechnical works and the unnatural/human managed water flow through a series of barrages and deviation of water from one basin to another, like in the biggest effluents (Bistra-Sebeş basins) cases on the upper Timiş River course (Curtean-Bănăduc et al., 2018), create effects of unnatural flushing of fishes over the Coștei Barrage or in the Bega Canal system, without the possibility of recolonization upstream even in critical/reproduction periods, mainly due to a not ecological flow management and the lack of fish ladders or passages.

Since significant fish fauna changes were highlighted in the upper Timiş River basin (Bănăduc et al., 2013; Curtean-Bănăduc et al., 2018), a natural continuity of these studies carry on in its middle curse through this specific research related to the Coştei hydrotechnical work effects on the fish resources. This approach in identifying historical significant negative effects of such a major hydrographical node, after this massive diversion scheme was finished, and in situ adapted mitigation technical optimum solution, is a new and innovative one in the studied region.

To enhance the aquatic ecosystems, we aim attention to the temporal and spatial structural modifications of fish fauna, brought about by a hydrotechnical diversion system construction and management, on a medium sized lotic system (Timiş River, Danube Basin). Here at first, the impact and magnitude of this historic diversion system was assessed based on the fish fauna capacity to indicate changes in the ecological status of a lotic system. Then the authors proposed a conceptual design for sustainable in situ adapted technical solution (by-pass) and specific management measures, to mitigate these effects on the local and regional fish fauna.

MATERIAL AND METHODS

In general due to the fact that the studied hydrotechnical node was built back in 1758, the same year when Linnaeus determined and named the studied fish of this paper too, it is impossible to make a comparison of fish fauna structure since that year, due to the taxonomical and scientific related names lacking assciated problems. The data concerning the historical impact of this major hydrotechnical diversion system's effects on the aquatic ecosystem's ichthyofauna is scarce in the area of interest, the reason for which this study was done based on the accessible period fiserman intervievs data (Annex 1/Table 1), and up-to-date field research information (Annex 2/Table 2). The main targets of this analysis were to establish the role of this significant hydrotechnical diversion system on the local and regional lotic ichthyofauna temporal and spatial transformation, and to design and suggest an in situ suitable alleviation technical work for the recovery of the identified ecological and economical losses. The studied old diversion system impact magnitude was assessed based on the fish fauna capacity to indicate changes in the ecological status of a lotic system. Fishes are key elements of aquatic ecosystems and are key components of ecosystem services in both qualitative and quantitative aspects, through the high number of taxa and their variety of ecological needs, adaptations, and functions (Nelson, 1995; Day, 2006), these making them ideal indicators for aquatic environment changes (López-López et al., 2015; Levin et al., 2019).

All the available reliable scientific information, discussions with old fishermen in the area, present fisherman captures analysis and fish identifications in upstream and downstream river sectors, were analyzed and compared in the last decades in the study area.

Based on the past and present fish species in the research area and current biological and ecological needs, an innovative in situ adapted technical solution (by-pass) for fish fauna rehabilitation was designed. This by-pass channel is based on an appropriate model of ecosystem response and the recovery of the aquatic community.

RESULTS

The decreasing trend of some fish species of economic interest in the Coştei hydrotechnical work area in the last century

The first ichthyologic systematic great Romanian book about fish fauna of Antipa (Antipa, 1909) included some small parts of the Banat region, and the first reliable complete Romanian book regarding the fish fauna including the Timiş River basin was published due to the greatest Romanian ichthyologist masterpiece (Bănărescu, 1964). Supplementary historic local data about fish were obtained in the past from the first author grand-grandfather (Agăsân Andraş, 1905-1985), who was for a lifetime in the area of interest a peasant-fisherman, and from one of the most active and experienced game fishermen family in the area of interest Adam Josef and his son Adam Helmut Johann since 1945 till the present (Annex 1/Table 1). Based on these information sources, it was possible for a spatio-temporal comparison of the fish fauna changes with present day fish data obtained for this research in the last decades on the field by the authors (Annex 2/Table 2). Due to the lack of very old reliable data, we cannot cover all the period since 1758 after the construction/deviation was made, but we cover the later period when the water demand by modern Timişoara city area became significant bigger, and when started new consolidation and elevation works at the diversion system (the 80's till 2004). As a result we identified an obvious decreasing trend in terms of many fish species for this period.

Silurus glanis Linnaeus, 1758 (Actinopterygii, Siluriformes, Siluridae) is freshwater, brackish, benthopelagic, non-migratory, and autochthonous fish species in the Danube Basin area with a maximum published weight of 306 kg (Antipa 1909; Bănărescu, 1964; Frimodt 1995; Oţel 2007; Bănăduc et al., 2015). This species natural distribution covers Europe and Asia, North, Baltic, Caspian, and Aral seas basins, as far north as southern Sweden and Finland; Aegean Sea basin in Maritza and from the Struma to Sperchios drainages, Turkey, was introduced in Europe and Lake Balkhash area in Kazakhstan (Frimodt, 1995; Kottelat and Freyhof, 2007).

The wels catfish has a high direct important economic value and a high nutritional value. The meat has a pleasant, fatty taste, it is eaten fresh in all its forms (Antipa, 1909; Frimodt, 1995).

Since the wells catfish is a very important economic fish species in freshwater fishing, has an accentuated continuous decreasing trend both in the upstream and the downstream of Coştei hydrotechnical work it represents a first big loss for the local economy. In addition to its direct economic value, this species has also a conservative value, being protected by the Berne Convention.

Cyprinus carpio Linnaeus, 1758 (Actinopterygii, Cypriniformes, Cyprinidae) is freshwater, brackish, benthopelagic, potamodromous, autochthonous fish species in the Danube Basin, with a published maximum weight of 40.1 kg (Antipa, 1909; Frimodt, 1995; Kottelat 1997; Oţel, 2007; Levin, 2019). Its range including wild populations cover Europe to Asia: Black, Caspian, and Aral seas basins, was introduced all over the world (Kottelat and Freyhof, 2007). A reophilic natural population in the Danube is accepted to be the ancestor group of the European species, now under threat (Machacek, 2007).

The common carp is the ultimate economically important freshwater fish species of Europe and in the temperate climatic zone. This exceptionally important commercial and game fish species in Romania too is the principal target for fishing in the lower sectors of medium and large lotic systems with a sweet meat, somewhat fat; being eat up in all imaginable ways: soup, fried, brine, baked, stuffed, salted, smoked, caviar salad, etc. (Antipa, 1909; Frimodt, 1995).

Since this fish species has an outstanding importance in freshwater fishing and aquaculture, its identified radical decreasing trend in both the upstream and downstream of river sector of Coştei hydrotechnical work represents a second big loss for the local economy. The natural form of this fish species is also of conservative interest not only of economic interest, being included in the IUCN Red List, as vulnerable (VU) (Kottelat and Freyhof, 2007).

Lota lota (Linnaeus, 1758) (Actinopterygii, Gadiformes, Lotidae) is freshwater, brackish, demersal, potamodromous, autochthonous fish species in the Danube Basin, with a maximum published weight of 34 kg (Antipa, 1909; Morrow, 1980; Frimodt, 1995; Oţel, 2007; Levin et al., 2019). Its natural distribution cover circumarctic area: Europe Loire drainage, Barents and Arctic Sea basins; upper Volga drainage; western Caspian basin; rivers draining to Black Sea; Rhône drainage (France); in Italy native only in Po drainage. In Siberia eastward to River Lena. North America: throughout Canada, Alaska and northern USA (south to Kentucky, Missouri, Wyoming and Washington (Page, 2011).

The burbot is an important economic species in freshwater fishing and has a profound decreasing trend in both the upstream and downstream of Coştei it represents a third loss for the local economy (Bănăduc et al., 2014).

Sander lucioperca (Linnaeus, 1758) (Actinopterygii, Perciformes, Percidae, Luciopercinae) is freshwater, brackish, pelagic, potamodromous, and autochthonous fish species in the Danube Basin area, with a maximum published weight of 20 kg (Antipa, 1909; Frimodt 1995; Oţel, 2007; Keith and Allardi, 2002; Levin and Woodford, 2019). Its natural distribution covers both Europe and Asia: Caspian, Baltic, Black, and Aral Sea basins; Elbe (North Sea basin) and Maritza (Aegean basin) drainages. North to about 65° N in Finland (Welcomme, 1988). The pike-perch is an important economic fish species in freshwater fishing and has a significant decreasing trend in both the upstream and downstream of Coştei hydrotechnical work area, it represents a fourth loss for the local economy (Bănăduc et al., 2014).

Tinca tinca (Linnaeus, 1758), (Actinopterygii, Cypriniformes, Cyprinidae, Tincinae) is freshwater, brackish, demersal, autochthonous fish species in the Danube Basin, with a maximum published weight of 7.5 kg (Antipa, 1909; Muus and Dahlström 1968, Frimodt 1995; Oţel 2007; Levin et al., 2019). Its natural distribution covers Eurasia: hypothesized as native in most Europe, in Asia native eastward to western Yenisei drainage (Kottelat and Freyhof, 2007).

The rudd is an important economic fish species in freshwater fishing and has an accentuated decreasing trend in both the upstream and downstream of Coştei hydrotechnical work it represents a fifth loss for the local economy.

Abramis brama (Linnaeus, 1758) (Actinopterygii, Cypriniformes, Cyprinidae, Leuciscinae) is freshwater, brackish, benthopelagic, autochthonous fish species in the Danube Basin, with a maximum published weight of six kg (Antipa, 1909; Bănărescu 1964; IGFA 1991; Oţel 2007; Bănăduc et al., 2014). Its natural distribution covers Europe and Asia: most European drainages from Adour (France) to Pechora (White Sea Basin), Aegean Sea basin, in Lake Volvi, and Struma and Maritza drainages. In Asia, from the Marmara Basin (Turkey) and eastward to the Aral Basin (Kottelat and Freyhof, 2007).

Since the freshwater bream is an important economic fish species in freshwater fishing, and has a high and accentuated continuous decreasing trend in both in the upstream and the downstream of the upstream Coştei hydrotechnical work it represents a sixth big loss for the local economy.

Rutilus rutilus (Linnaeus, 1758), (Actinopterygii, Cypriniformes, Cyprinidae, Leuciscine) is freshwater, brackish, benthopelagic, autochthonous fish species in the Danube Basin, with a maximum published weight of 1.8 kg (Antipa, 1909; Bănărescu 1964; IGFA 1991; Oţel, 2007; Bănăduc et al., 2014). Its natural distribution covers Europe: north to Pyrenees and Alps, eastward to Ural and Eya drainages (Caspian Basin); Aegean Basin in Pinios, Vardar, Vegoritis, Kastoria, Struma, and Maritza drainages. Asia: Marmara Basin and lower Sakarya in Anatolia, Aral Basin, and Siberia from Ob eastward to Lena drainages (Kottelat and Freyhof, 2007).

The roach is an important economic fish species in freshwater fishing and has an accentuated decreasing trend in both the upstream and downstream of Coştei hydrotechnical work it represents a seventh loss for the local economy.

In situ adapted meandering bypass for the bidirectional and volitional movement of fish over the overflow threshold within the Coştei hydrotechnical node

Conceptual design

For the research area, the key challenge was to design a migration system, so as not to affect the structure and functionality of the overflow dam and its construction elements, namely the left bank of the embankment (dam protected by a wall, over a length of 200 m and protected by grassing over a length of 165 m). Also, the location of a frontal migration system has been avoided, because it is very difficult to achieve access for maintenance.

The solution is to create a fish migration/passage system represented by a meandering by-pass. It is designed for the upstream, downstream, and volitional migration/displacement of the ichthyofauna present in the analyzed area, and also in upstream and downstream sectors.

As the location area of this by-pass, the left bank was selected (a flat plain vast agricultural land), due to the spatial constraints at the level of the right bank (national and local roads and hydrotechnical infrastructure components related to the Coştei hydrotechnical node: i.e. pipeline equipped with drawer valve in the water chamber, and Coştei locality different buildings), as well as the river slope in the area of the analyzed spillway threshold.

Principle of operation

Although from the point of view of space there is the possibility of creating a classic by-pass channel, we opted for a meandering by-pass channel (Fig. 7).

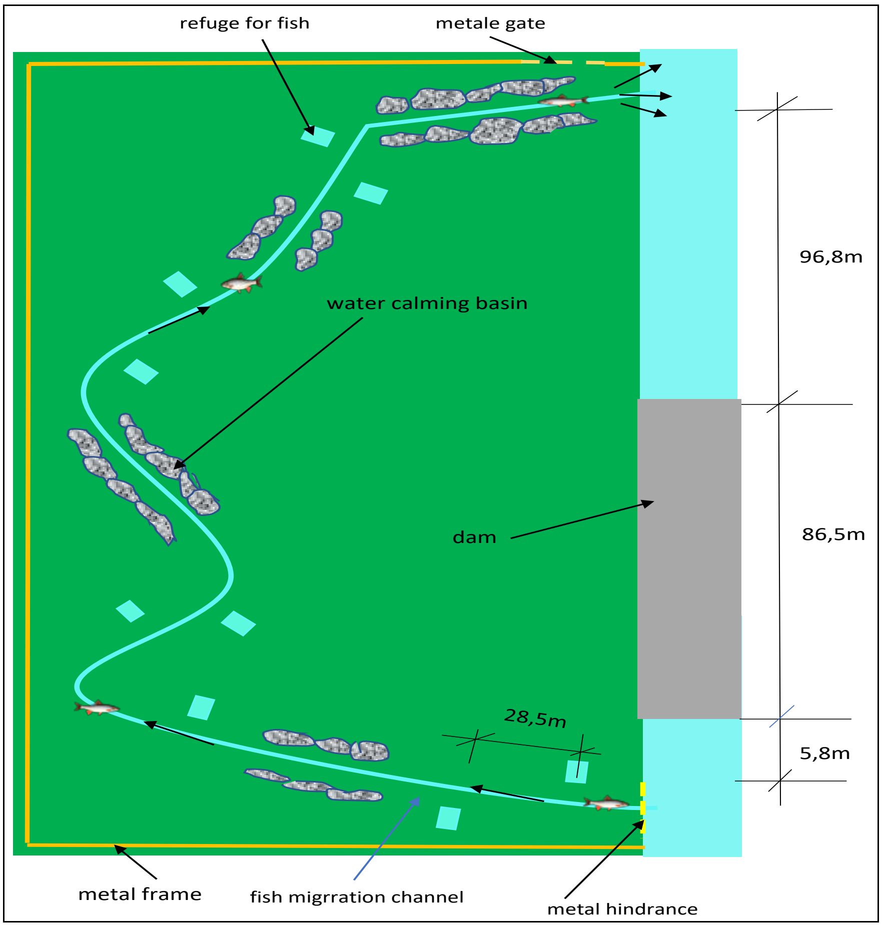

Figure 7: General indicative scheme of the meandering by-pass channel – plan view –.

The inequality in water level between the upstream and the downstream area of the overflow threshold would have led to a by-pass with a too long length. Thus, the aim was to avoid the occurrence of clogging phenomenon, by creating a by-pass that will have the following characteristics: (i) the canal will have a length of approximately 660 m and will be composed of three meanders with fish shelters and rest pools every 28.5 m on both banks; (ii) the water entry in the by-pass channel is located at a distance of 16 m upstream of the overflow ridge, in the area of the left bank; (iii) the water outlet area of the by-pass channel is located at a distance of 96.8 m from the foot of the downstream facing of the overflow threshold (in the axis of the transverse channel). In rest and shelter basins there is always a sufficient water level to allow the fish to re-enter the main stream of the fish migration channel.

Components and dimensions

Description of the meandering by-pass channel

The meandering by-pass canal, proposed for this case study, will have a total length of approximately 660 m. The upstream end of this battlement/crenel (Fig. 8) will be equipped with a dam, fixed on a metal frame (vertical sliding) operated by means of a mechanical reducer and a threaded metal bar (Fig. 9).

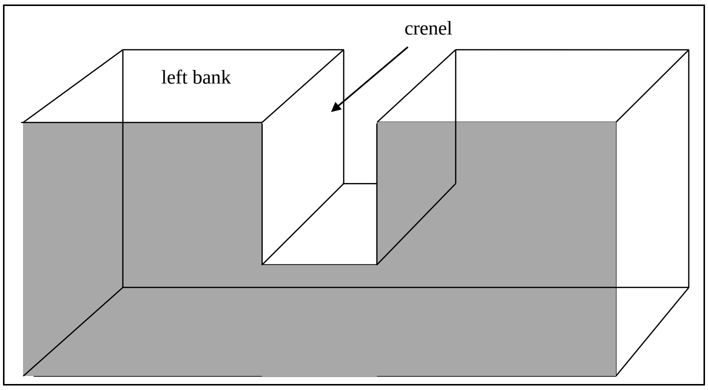

Figure 8: Making the battlement/crenel in the left bank – indicative scheme.

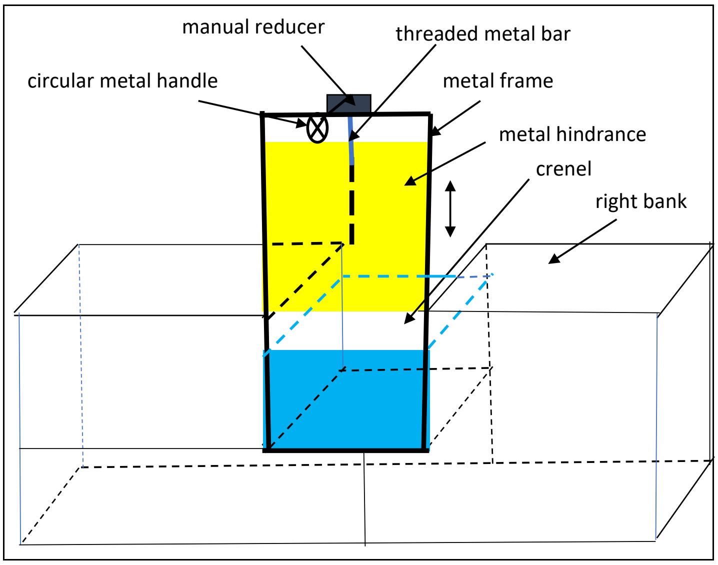

Figure 9: Positioning the dam on the metal frame – indicative scheme.

If for various reasons (e.g. repair work, maintenance, lack of water) it is not desired for the water to flow through the migration system, this dam will be closed.

The downstream end of the meandering by-pass channel will penetrate through the left concrete bank, reaching the watercourse, at a distance of approximately 96.8 m from the foot of the downstream facing (Fig. 10a).

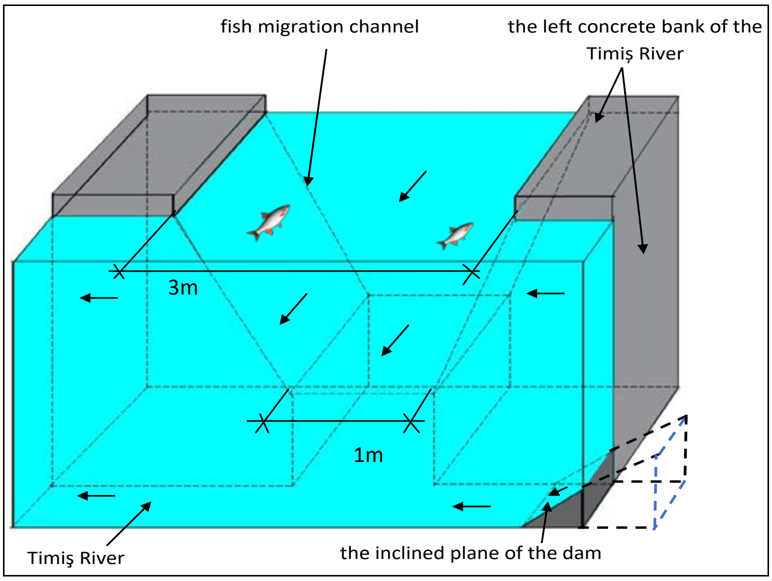

Figure 10a: Positioning the downstream end (entrance) of the meandering by-pass channel – indicative scheme.

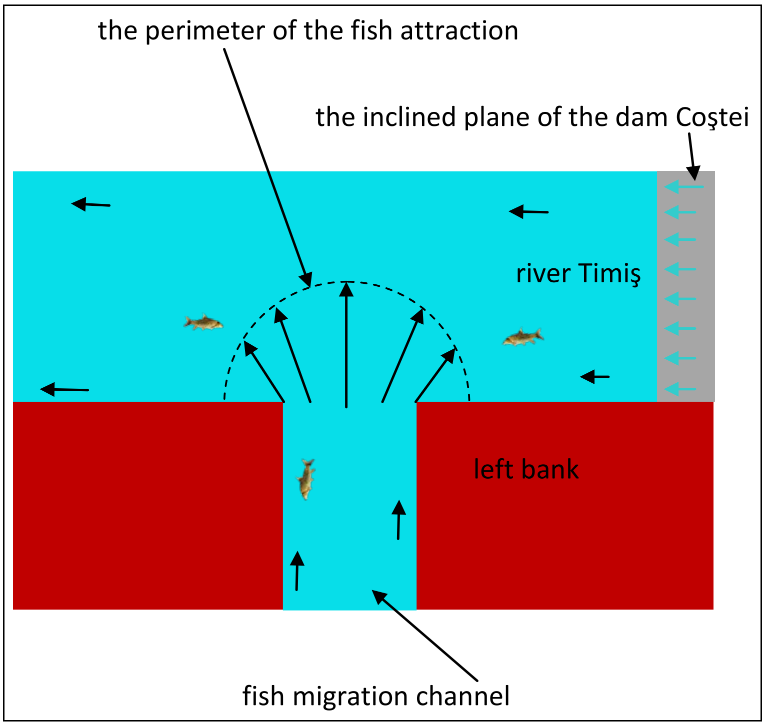

Figure 10b: Positioning the perimeter of the fish attraction – indicative scheme.

In the sense of upstream migration, this will correspond to the area of entry (entrance) of the fish into the meandering channel. Given the amount of water flowing through the by-pass channel, the place of conflict between the fish migration channel and the Timiş River will be detected by fish climbing along the right bank or will be detected by fish moving from the left bank to the right bank. Knowing that migratory fish feel the turbulence in the water from a distance is quite large in our case the radius of the semicircle of attraction (perimeter of attraction) is about three m (Fig. 10.b).

The by-pass channel will have a trapezoidal shape, and will be made of concrete and arranged with stones that also act as sinks (Fig. 11a). On both sides of the concrete channel for the migration of fish, along with it, at distances of about 40 m, will be arranged alternately, concrete steps, necessary for the purpose of interventions (damage, maintenance) (Fig. 11b).

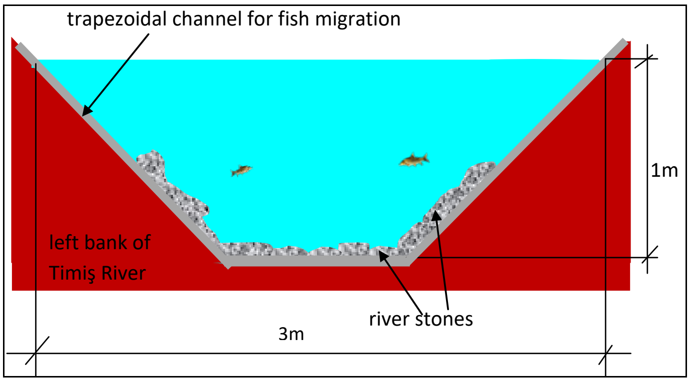

Figure 11a: By-pass channel in cross section – indicative scheme.

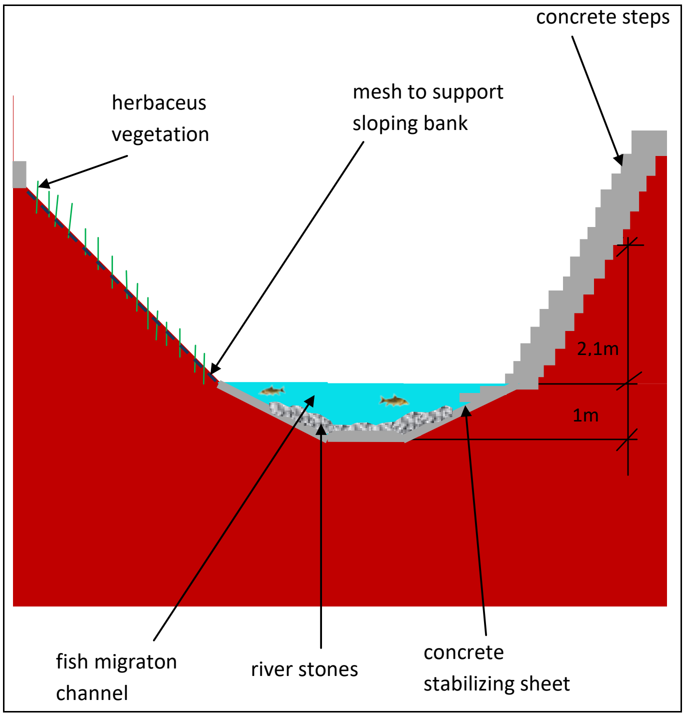

Figure 11b: By-pass channel in cross section – indicative scheme.

Description of resting pools and fish shelters

Taking into account that the ichthyofauna of the study area is represented mainly by cyprinids, the fish shelters will be arranged every 28.5 meters, alternately, inside the banks (by-pass channel) (Fig. 12). They will have a parallelepiped shape, will be paved, and will have the following approximate dimensions: height and depth of ~ one m, and length of ~ three m. Fish shelters, like the entire by-pass, will be flanked by sloping banks (Fig. 11a, b). Their stabilization will be achieved with the help of anti-erosion mattresses and vegetation (herbs).

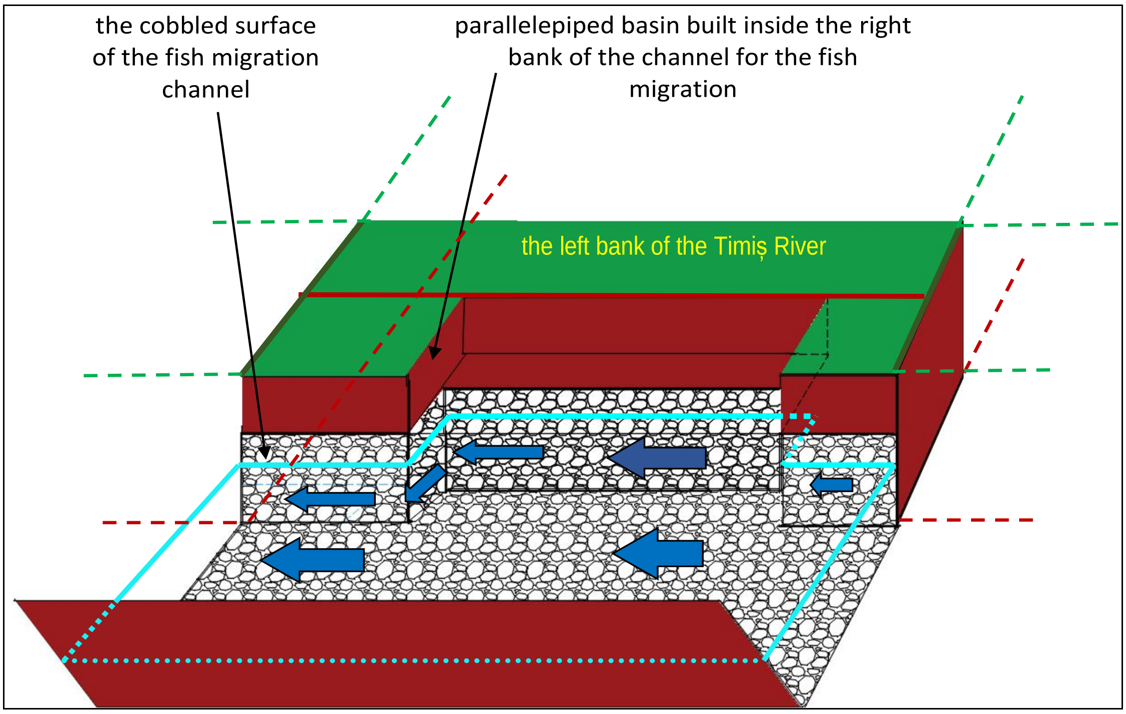

Figure 12: Positioning of fish shelters at the level of the meandering by-pass channel indicative scheme.

Maintenance

Any component can be replaced if damaged. If quality materials are used and the system is built according to the project, it can last a long time.

DISCUSSION

The general agreement of the majority of researchers is that there is a demand for an exhaustive strategy for assessment of diversions and identify direct, indirect, cumulative, and synergic impacts (Wilson et al., 1999; Barbe et al., 2000; Winer and Raphelt et al., 2005; Meselhe et al., 2006).

In the evaluation of impacts of diversions on a broader spatial scale and long-term various changes in the habitats must be considered. Also, various angles of approach which reveal habitat and biocoenoses changes for example habitat changes or succession of riverine vegetation should be studied due to their direct effect on flow within the lotic system, and indirect on aquatic and semi-aquatic animal biota which depends on it, including fish (Curtean-Bănăduc et al., 2014).

The Timiş River in the studied sector but not only (Bănăduc et al., 2013; Curtean-Bănăduc et al., 2018) has been forced to change some of its main ecologic characteristics to fulfil some of the regional human settlements needs, mainly to the needs of a big city (Timişoara) and its metropolitan area, located in a near poorer in water watershed (Bega Basin), consequently in a context of a not ecological technical approach, many natural characteristics of the Timiş lotic system were lost (dynamic balance equilibrium, integrality, homeostazy, resilience, predictability, productivity, etc).

The Coştei diversion system impact was revealed based on the local and regional fish fauna ecological status changes. This approach was based on the fish indicator capacity for aquatic environment changes (López-López and Sedeño-Díaz, 2015; Levin et al., 2019).

The Timiş lotic system ichthyofauna structure was unquestionably altered, due to the drastically hydrogeomorpholgical river changes after the Coştei hydrographical node construction and modernization mainly in terms of water volume, flow and sediment diversion capacity, runoff regime, speed, water quality, etc.

In the situations in which a natural fluctuating of the lotic systems dynamics has been identified as essential to the sustainability of the aquatic systems receiving the diversion flows (Day et al., 1995), the diminishing of the flow induced in Timiş River the more intense rate of sedimentation, with modifications in riverbed morphology, important factors for habitat features changes, and therefore in fish fauna structure modifications. In this respect, it is enough to underline the fact that in the last two centuries were many periods when all the water has deviated to Bega River channel, and nothing remains in the downstream Timiş River (Fig. 5), with exception of few small areas with water from the hyporheic sources (Fig. 6).

This diversion impact is significant, riverbed hydrogeomorphological modifications such as flood routing, sediment load, channel bed aggradations, channel bed degradation, sediment sorting along channel reach, sediment load variation with changing discharge, velocity distribution, secondary circulation, sediment bar formation, shear stress distribution, bedload transport distribution, flow distribution at the bifurcation, and sediment load distribution at bifurcation were followed by ecologic nonlinear/nonproportional to the stimulus responses (Schumman, 1977), highlighted in this study by a skewed ichthyofauna structure, and with decreasing economic benefits related to animal/fish protein accessibility.

Despite of the fact that regarding major hydraulic works it should be established the ecological flow downstream of works and it should be studied their potential impact, and regulating the transfer of water from one reservoir to another so none of the reservoirs should be under or over the optimal volume, no detailed complex hydrogeomorphologic-ecologic analysis was conducted till now about the Coştei diversion node effects before or since its building in 1758, and also not about many of the upstream hydrological works of this basin.

After such a long period of not ecological construction and management of Coştei diversion system, seven main species with high direct economic importance disappeared from the upstream sector, or decrease significantly both in the upstream and downstream sectors, a significant loss for the local natural resources exploitation potential. Also, another nine direct economic important fish species populations which still exists in the upstream lotic sectors are more or less isolated by the lower part of the Timiş River and through it by the adjacent hydrographical nets of Tisza and Danube, having much smaller populations than the river usually supports in the past. Adding to those are more than ten indirect important economic fish species also more or less isolated in the upstream river sectors.

The exposure of this lotic system and its fishes populations to many different coincident or sequential stressors intensifies ecological impacts and vastly complicates restoration and conservation planning, especially where spatially diffuse stressors syndromes span multiple management agencies. The management of freshwater fishes under scenarios of climate change may be the greatest conservation challenge in the studied region where aquatic ecosystems are already exposed to multiple interacting stressors.

Recovery programs should range from individual species to the fauna of entire river basins. Fish conservation should involve the protection and improvement of their habitats and the establishment of refuge habitats. A remarkable effort at basin scale is the rehabilitation of fish communities throughout Timiş River basin, where fishes are subject to severe impacts by many stressors.

In this context, the recovery programs needs an integrated catchment management, restoration of aquatic habitats, dam flow ecological management or removal, provision of environmental flows, restoration of riparian and floodplain processes. Fish populations can be rehabilitated by applying appropriate regulations (e.g. catch and release), no-take zones in critical areas for breeding and recruitment, and even managed relocation and reintroductions. Human activities and stressors that threaten freshwater fishes are likely to become more widespread, intense and damaging unless they are curbed through prevention, improved management, and restoration and adaptation programs.

Even with the most advanced risk evaluation, conservation plans design, fisheries restoration and management tools, enhancements in fish conservation present scientists, managers and citizens with critical challenges and trade-offs, particularly under unusual scenarios of threat under climatic change.

Human pressures on fish must be limited to the maximum degree possible, within constraints of food security, to restore resilience and allow human-assisted adaptations to take effect in the novel and managed environments. Implementation, monitoring and review of fish conservation and management regimes must feed new information back and forth between researchers, managers, and citizens to achieve consensus on what is worth doing, and achievable, in the uncharted waters of the future.

Despite of the revolutionary bioeconomical and ecoeconomical concepts imagined first by the Romanian researcher Nicholas Georgescu-Roegen (IGFA, 1991; Daly, 1999), and developed to be used including in the Romanian ichthyofauna resources context by Grigore Antipa (Antipa, 1909) the not ecological approaches are still a way of acting in the case of Coştei diversion system and not only. Fast ecological approaches and technical solutions are needed to recover at least a part of the economical and ecological losses in the studied region ichthyofauna resources.

Ichthyocenoses are recognized as key components for lotic ecosystems. The structure (qualitative and quantitative) and dynamics (spatial and temporal) of fish communities are conditioned by the diversity and quality of characteristic habitats (natural or man-made), the quantity and quality of available trophic resources, interaction with other communities, etc. (Lasne et al., 2007; Kennen et al., 2008; Hermoso et al., 2009; Infante et al., 2009). The skewed structure of the ichthyofauna negatively influenced by the Coştei diversion system construction and management over more than two centuries, in a general and complex human influenced river system, obviously reflect drastic long-term ecosystem changes, including on fish fauna.

If no specific adapted measures will urgently be taken, like those proposed in this work, in the global changes actual situation (Oprean, 2012) the climate ecological trend will continue possibly in this revealed direction new unexpected ecological nonlinear/nonproportional effects.

CONCLUSIONS

The Timiş River watershed former and current water resource inapropriate management way is inaccurate and potentially harmful for the human enterprise. The proposed technical solution implementation can be a successful intervention to restore Timiş River ecosystems in a long term sustainable way, prevent local extinctions of some fish species and encourage more local and regional economic activities, and support from a sustainable perspective the fish species local and regional populations ecological status.

The upstream and downstream sectors of Coştei hydrographical node, are characterized by similar physiogeographic characteristics, which include location, catchment size, geological structure, drainage density, land denivelations, and land use, but the studied diversion system in the context of more other significant human impacts in the basin, induced long term habitat changes and drastic fish fauna changes, especially in the upstream river sector.

The Coştei diversion system ecological problems are important not only for the heavily human impacted Timiş Basin fish fauna, but in a larger frame of ecological human induced fragmentation for the Tisza Basin fish fauna too.

The specific on-site adapted technical solution proposes the realization of a meandering bypass for the bidirectional and volitional movement of fish over the overflow threshold within the hydrotechnical node, helping in improving the fish populations' connectivity and ecological status for the entire Timiş and Tisza basins.

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Annex 1/Table 1: Historic local data about fish obtained from local top fisherman about the species of interest trend; decreasing abundance ↓, increasing abundance ↑.

Fish species / Interviewed top local fisherman	*Silurus glanis*	*Cyprinus carpio*	*Lota lota*	*Sander lucioperca*	*Tinca tinca*	*Abramis brama*	*Rutilus rutilus*
Agăsân Andraș Covered period 1905-1985	↓	↓	↓	↓	↓	↓	↓
Adam Josef and Adam Helmut Johann Covered period 1945-2020	↓	↓	↓	↓	↓	↓	↓

Annex 2/Table 2a: Local data about fish species of interest trend obtained from 10 fisherman/one day/one year; present species in the dedicated for fish species of interest fisherman capture + (minimum 10 hours of fishing per day), absent species –.

10 local on site fisherman captures analyse	Year	*Silurus glanis*	*Cyprinus carpio*	*Lota lota*	*Sander lucioperca*	*Tinca tinca*	*Abramis brama*	*Rutilus rutilus*
	1996							
Fishermen 1		+	–	–	–	–	–	–
Fishermen 2		–	+	+	–	–	+	–
Fishermen 3		–	–	–	–	–	–	–
Fishermen 4		+	–	+	–	+	–	+
Fishermen 5		–	–	–	–	–	+	–
Fishermen 6		–	–	+	–	–	–	–
Fishermen 7		–	–	–	–	–	–	–
Fishermen 8		–	–	+	–	–	–	–
Fishermen 9		–	–	–	–	–	–	–
Fishermen 10		+	–	–	–	–	–	–
	1999							
Fishermen 1		–	+	–	–	–	–	–
Fishermen 2		–	+	–	–	–	–	+
Fishermen 3		–	+	–	–	–	–	–
Fishermen 4		–	–	–	+	–	–	–
Fishermen 5		–	–	+	–	+	+	–
Fishermen 6		+	–	+	–	+	+	–
Fishermen 7		–	–	–	–	+	–	–
Fishermen 8		–	–	–	–	+	–	–
Fishermen 9		–	–	–	–	–	–	–
Fishermen 10		–	–	–	–	–	–	–

Annex 2/Table 2b: Local data about fish species of interest trend obtained from 10 fisherman/one day/one year; present species in the dedicated for fish species of interest fisherman capture + (minimum 10 hours of fishing per day), absent species –.

	2002							
Fishermen 1		–	–	–	–	–	–	–
Fishermen 2		–	–	–	–	–	–	–
Fishermen 3		+	–	–	–	–	–	–
Fishermen 4		–	–	–	–	–	–	–
Fishermen 5		–	–	+	–	–	–	–
Fishermen 6		+	–	–	–	–	–	–
Fishermen 7		–	–	–	–	–	–	+
Fishermen 8		–	–	–	–	–	–	+
Fishermen 9		+	–	–	+	–	–	–
Fishermen 10		+	–	–	–	–	–	–
	2005							
Fishermen 1		–	–	–	–	–	–	–
Fishermen 2		–	–	+	–	–	–	–
Fishermen 3		–	–	+	–	–	–	–
Fishermen 4		–	+	–	–	+	+	–
Fishermen 5		+	+	–	–	–	–	–
Fishermen 6		–	–	–	–	–	–	–
Fishermen 7		–	–	–	–	–	–	–
Fishermen 8		–	–	–	–	–	–	–
Fishermen 9		–	–	–	–	–	–	–
Fishermen 10		–	–	–	–	–	–	–

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Annex 2/Table 2c: Local data about fish species of interest trend obtained from 10 fisherman/one day/one year; present species in the dedicated for fish species of interest fisherman capture + (minimum 10 hours of fishing per day), absent species –.

	2008			–			–	–
Fishermen 1		–	–	–	–	–	+	–
Fishermen 2		–	–	–	–	–	–	–
Fishermen 3		–	–	–	–	–	–	–
Fishermen 4		–	–	–	–	–	–	–
Fishermen 5		–	–	–	–	–	–	–
Fishermen 6		–	–	–	–	–	–	–
Fishermen 7		–	–	–	–	–	–	–
Fishermen 8		–	–	–	–	–	–	+
Fishermen 9		–	–	–	–	–	–	–
Fishermen 10		+	–	–	–	–	–	–
	2011							
Fishermen 1		–	–	–	–	–	–	–
Fishermen 2		–	–	–	–	–	–	–
Fishermen 3		–	–	+	–	–	–	–
Fishermen 4		+	–	–	–	–	–	–
Fishermen 5		–	–	–	–	–	–	–
Fishermen 6		–	–	–	–	–	–	–
Fishermen 7		+	–	–	–	–	–	–
Fishermen 8		–	–	–	–	–	–	–
Fishermen 9		–	–	–	–	–	–	–
Fishermen 10		–	–	–	–	–	–	–

Annex 2/Table 2d: Local data about fish species of interest trend obtained from 10 fisherman/one day/one year; present species in the dedicated for fish species of interest fisherman capture + (minimum 10 hours of fishing per day), absent species –.

	2014							
Fishermen 1		–	+	–	–	–	–	+
Fishermen 2		–	–	–	–	–	–	–
Fishermen 3		–	–	–	–	+	–	–
Fishermen 4		–	–	–	–	–	–	–
Fishermen 5		–	–	–	–	–	–	–
Fishermen 6		–	–	+	–	–	–	–
Fishermen 7		–	–	–	–	–	–	–
Fishermen 8		–	–	–	–	–	–	–
Fishermen 9		–	–	–	–	–	–	–
Fishermen 10		–	–	–	–	–	–	–
	2017							
Fishermen 1		–	–	–	–	–	–	–
Fishermen 2		–	–	–	–	–	–	–
Fishermen 3		–	–	–	–	–	–	–
Fishermen 4		–	–	–	–	–	–	–
Fishermen 5		–	–	–	–	–	–	–
Fishermen 6		–	–	–	–	–	–	–
Fishermen 7		–	–	–	–	–	–	–
Fishermen 8		+	–	–	–	–	–	–
Fishermen 9		–	–	–	–	–	–	–
Fishermen 10		–	–	–	–	–	–	–

Annex 2/Table 2e: Local data about fish species of interest trend obtained from 10 fisherman/one day/one year; present species in the dedicated for fish species of interest fisherman capture + (minimum 10 hours of fishing per day), absent species –.

	2020							
Fishermen 1		–	–	–	–	–	–	–
Fishermen 2		–	–	–	–	–	–	–
Fishermen 3		–	–	–	–	–	–	–
Fishermen 4		–	–	–	–	–	–	–
Fishermen 5		–	–	–	–	–	–	–
Fishermen 6		–	–	–	–	–	–	–
Fishermen 7		–	–	–	–	–	–	–
Fishermen 8		–	–	–	–	–	–	–
Fishermen 9		–	–	–	–	–	–	–
Fishermen 10		–	–	–	–	–	–	–