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Ichthyofauna of the Brdy Protected Landscape Area in Central Bohemia

Master's thesis

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Declaration

"I hereby declare that this thesis entitled Ichthyofauna of the Brdy Protected Landscape Area in Central Bohemia is my own work and all the sources have been quoted and acknowledged by means of complete references."

In Prague 27. 4. 2017

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Anežka Ťuláková

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Abstract

The Brdy Protected Landscape Area is situated in the former military area of Brdy in the central part of Czech Republic. The aim of the thesis was to determine the fish species diversity, fish abundance, fish biomass, age structure of selected species from fish scales in the context of different environmental and anthropogenic variables in the Brdy Protected Landscape Area. Particularly, investigation was focused on questions how fish abundance, species diversity and biomass were related to the measured parameters pH, conductivity, water width and to the qualitative parameters type of the stream bed (natural/regulated), presence/absence of aquatic vegetation and presence/absence of pools. Further aim was to compare populations of certain fish species in 2000 and in 2016. The ichthyological survey was conducted by the standard method of electrofishing via battery aggregate. Data were collected from 48 profiles of 18 localities and altogether were detected one lamprey species and 14 fish species: *Lampetra planeri, Salmo trutta, Cottus gobio, Perca fluviatilis, Rutilus rutilus, Phoxinus phoxinus, Lota lota, Barbatula barbatula, Esox lucius, Anguilla anguilla, Tinca tinca, Salvelinus fontinalis, Scardinius erythrophtalmus,* Tiger trout and *Gobio gobio*. Finally, it was surveyed that water width and presence of aquatic vegetation had effect on species diversity. It was confirmed that natural type of stream bed, presence of aquatic vegetation and presence of pools increased numbers of individuals of different age groups of certain species on selected profiles. Differences of numbers of individuals of species on selected localities in 2000 and in 2016 were described on common chart, however they were not statistically significant. And then separately for individual fish species as well, where the decline of Eurasian minnows, Stone loaches, Gudgeons and increase of Brown trouts and Bullheads were found. Consequently, study gives a comprehensive and overall review of actual ichthyofauna of the Brdy PLA.

Keywords: fish, protected area, species diversity, abundance, biomass, environment

Abstrakt

Chráněná krajinná oblast Brdy je situována v bývalém areálu vojenského újezdu Brdy v centrální části České republiky. Cílem práce bylo ze získaných dat určit druhovou diverzitu ryb, abundanci ryb, biomasu, věkovou strukturu rybí populace vybraných druhů na základě rybích šupin, změřit fyzikální a chemické parametry vody – pH, konduktivita, celkové množství rozpuštěných látek na většině zkoumaných profilů, popsat kvalitativní parametry jako typ koryta (regulované nebo přirozené), přítomnost či absence vodní vegetace a přítomnost či absence tůní a zjistit jejich efekt na diverzitu, abundanci, biomasu a věkové složení. Dalším cílem bylo srovnání populací ryb z roku 2000 a 2016. Ichtyologický průzkum byl proveden standardní metodou lovu za pomoci bateriového agregátu. Dohromady bylo prozkoumáno 48 profilů na 18 tocích a celkem bylo zaznamenáno jeden druh mihule a 14 druhů ryb: *Lampetra planeri, Salmo trutta, Cottus gobio, Perca fluviatilis, Rutilus rutilus, Phoxinus phoxinus, Lota lota, Barbatula barbatula, Esox lucius, Anguilla anguilla, Tinca tinca, Salvelinus fontinalis, Scardinius erythrophtalmus,* siven x pstruh a *Gobio gobio*. Výsledky ukázaly, že šířka vody a přítomnost vodní vegetace měly vliv na druhovou diverzitu ryb. Dále bylo zjištěno, že typ přirozeného koryta, přítomnost vodní vegetace a přítomnost tůní zvyšovaly počty jedinců různých věkových skupin u vybraných druhů ryb na jednotlivých profilech. Také byly popsány rozdíly počtů jedinců jednotlivých druhů na vybraných tocích z let 2000 a 2016 na společném grafu, které však nebyly signifikantní. A dále grafy porovnávající jednotlivé druhy v roce 2000 a 2016, kde byly zjištěny poklesy u jedinců *Phoxinus phoxinus*, *Barbatula barbatula*, *Gobio gobio* a nárůst u jedinců *Salmo trutta* a *Cottus gobio*. Tato studie předkládá celkové detailní zpracování ichtyofauny v CHKO Brdy.

Klíčová slova: ryby, chráněné území, druhová diverzita, početnost populace, biomasa, prostředí

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List of abbreviations

e.g. – exempli gratia - for example

etc. – et cetera – and the other things

i.e. – id est – that is

app. - approximately

AOPK ČR – Agentura ochrany přírody a krajiny České republiky (= NCA in English below)

ČHMÚ – Český hydrometeorologický ústav (Czech Hydrometeorological Institute)

ČÚZK – Český úřad zeměměřický a katastrální (State Administration of Land Surveying and Cadastre)

ArcGIS – Geographical Information System

NCA – Nature Conservation Agency of the Czech Republic

PLA – Protected Landscape Area

SAC – Special Area of Conservation

SCI – Sites of Community Importance

TDS – Total Dissolved Solids

1 Introduction and literature review

There are more than half of the 55, 000 fish species of living vertebrates (Helfman et al., 2009). Fishes exhibit enormous diversity in their morphology, in the habitats they occupy and in their biology (Nelson, 2006).

Fish species are important and integral part of Brdy fauna. Commonly, there are present fish species of trout and grayling fish zone (Kubečka, 2014) and several endangered species as European brook lamprey, Eurasian minnow, and Bullhead. Some of these fish species could be considered as bioindicators for balanced water environment (Hanel and Andreska, 2006). Nowadays, the ichthyofauna could be threatened by the human impact, which means the fishery management, intervention to natural conditions and regulation of water streams (Cílek et al., 2015).

1.1 Fish diversity and environmental aspects

In common, chemical and physical composition of natural water influences the environmental perspective of the fresh waters. It is essential that in natural water occurs solutes, weathering and erosion of rocks and soils, precipitation reactions occurring under the ground superficies, gases, aerosols and finally also, the human activity as agricultural, pollution and cultural effects (Hem, 1959). Men significantly interfere, influence, and change both physical and chemical water parameters and the hydro – morphologic characteristics within management and conversion of landscape (Adámek, 1997). Humpl and Pivnička (2006) claims that the variability in fish assemblages is in general influenced by landscape morphology and attributes (Angermeier and Winston, 1999), or by the stream size or altitude (Schlosser 1982; Lyons 1996; Brown 2000), or else by stocking of economically eminent fishes (the brown trout, carp or pike) (Pivnička and Humpl, 2004). Moreover, main goal of ecology is to determine factors and environmental influences responsible for models and changes in biodiversity system and assembly structure along rates of resource and environmental conditions at a variety of spatial scales (Jacobson and Peres – Neto, 2010). In lotic freshwater systems, hydrological characteristics act as multilevel physical factors in terms of temporary variability. In accordance, morphological, behavioural and lifetime attributes of aquatic organisms respond to these factors (Bunn and Arthington, 2002; Lytle and Poff, 2004; Beachum et al., 2016). In the study about factors influencing the structure and spatial distribution of fishes in Jaú River, the stream size, the variability of benthic substrates and the diversity of the habitats had influence on the trophic structure and diversity of stream fish communities (Kemenes and Forsberg, 2014). According to Hanel and Lusk (2005), the basic physical and chemical water characteristics are the temperature of the water, content of oxygen in water, content of organic material and solids, pH values and content of toxic compounds. Furthermore, as hydro – morphologic characteristics of water streams or else environmental factors are embodied flow velocity, water depth, water width, dynamics of water flow, meandering and segmentation of bed, transvers profile of bed and its variety, character and segmentation of the bottom, structure of sediment and substrate and their area, character and segmentation of the banks, aquatic vegetation, bank vegetation and water shading, presence of pools, landscape activity connected with erosion and transporting action. As well, the character of hydrological system is one of the most important factors determining the condition and further development of ichthyofauna (Lusk et al., 2002a). Relationships between environmental parameters and the biocenosis is substantial. Ecological parameters of such biocenoses as abundance, biomass and species diversity are crucial for understanding the role of biota in ecosystems (Brosse and Lek, 2000). Further, the review is focused on studied influencing factors.

Morphological, abiotic and biotic factors

Horký (2014) claims that the level of environmental variability defines the local community level to be more influenced by abiotic or biotic factors. Abiotic factors as flow rate (Schlosser, 1985) or habitat heterogeneity (Gorman and Karr, 1987) play roles in unstable and frequently changing environment (Capone and Kushlan, 1991), meanwhile in relative stable environment the fish composition is influenced by biotic factors as competition (Ross et al., 1985), interaction between predator and his prey (Moyle and Vondracek, 1985) or feeding habits of fishes which vary according to the habitat (Bojsen and Barriga, 2002). Fish abundance, fish biomass and fish growth (fish age) are influenced by abiotic factors and by the aliment (Pivnička, 2002). Fish biomass is a result of the fish growth. The aliment and environmental factors limit growth of the fishes. These are mainly heat, temperature, light, amount of dissolved oxygen in water and moreover, by the competition (Pivnička, 2002). Streams, swamps, small rivers and seasonal pools are generally highly variable even without any anthropogenic influence (Ostrand and Wilde, 2002). According to Minshall et al. (1983), the smaller the stream, the more dependent the biota is on leaf litter habitats and allochthonous energy derived directly or indirectly from the forest. The diversity and abundance of stream fish communities has also been associated with physical characteristics of the fluvial environment (Pouilly et al., 2006; Romanuk et al., 2006). Variation in channel depth of stream habitats controls the longitudinal distribution and diversity of fish assemblages (Sheldon, 1968). Niu and Knouft (2017) claims that in particular, fish diversity rises with increasing stream variability when majority of species have opportunistic and equipoise lifetime strategies yielding to hydrological variability. Equally, according to Preston (1962), the species diversity increases with the size of area. Fish assemblages are strongly related to different stream pH in English streams. Following fish types in terms of life strategies, act differently on various stream pH. Collectors, predators and shredders occurred only in acid streams. On the other hand, collector and predator species increased in more basic sites and, also grazes and filter feeders occurred (Townsend et al., 1983). Tolerable pH range is 6.5 – 8.5 for fish species. At pH 4.8 – 5.0 damage of organism occurs and pH over 9.2 to 10.8 causes loss of appetite and restlessness. Low pH values inhibit larval development and decrease ability to regenerate (Adámek, 1992; Máchová and Kouřil, 1992; Vykusová, 1992; Svobodová, 1992). Acidification of water streams is determined by the character of soils and rocks, by the occurrence and amount of peat – bogs, the altitude, the intensity of precipitation, forestry and agricultural management and by the sulphur oxidation (Dickson, 1983). Another factor influencing water streams is conductivity. Conductivity represents how easily electricity is flowing through the water environment. Conductivity is thus in correlation with dissolved solids and salts. This parameter also depends on the water temperature. As the temperature of water increases, the conductivity does as well. Fish and another freshwater organism cannot tolerate high increase of saltiness, dissolved solids, and conductivity, when the conductivity is indirect index of saltiness and dissolved solids. Conductivity outside range 0 to 200 $\mu S. cm^{-1}$ and 200 to 1000 $\mu S. cm^{-1}$ shows that the water environment is not suitable for certain freshwater fish species (Horne and Goldman, 1994 U.S. E.P.A., 2017). As for the qualitative environmental factors, Rozas and Odum (1988) revealed, that predation pressure is lower in areas with submerged aquatic vegetation and suggest that foraging success is significantly higher in the parts with aquatic vegetation. Also, aquatic vegetation affords protection against predators (Valdimarsson and Metcalfe, 1998) and the fishes foraging there may have higher growth rates, higher abundance, lower mortality, and higher fecundity (Rozas and Odum, 1988). Fish also hide from extreme sunshine (Valdimarsson, et al., 1997), high flow – rates (Valdimarsson and Metcalfe, 1998), or if the temperatures are low (Heggenes et al., 1993). In general, shelters decrease cannibalism (Britz and Pienaar, 1992), aggression (Hecht and Appelbaum, 1988) and due to decreasing consumption of energy, they also increase fish growth (Benhaïm et al., 2009). Water environment rich in shelters enables the higher fish abundance (Eklöv, 1997). As Slavík (2014) ascertained, flows with the stream bed shaped by natural flow effect, spontaneous sedimentation, occurrence of submerge aquatic vegetation and dead wood materials represents water environment with optimal level of shelters. On the contrary, channelized and regulated flows with fortified banks and shorelines and with straightened stream beds, provides shelters on minimal level (Slavík, 2014). Pools could be classified as naturally or artificially created, small, undrainable water system. The average maximal depth should be two meters and therefore the water is sufficiently warm and there is high amount of nutrients, high species diversity, but the energy metabolism there hardly takes place (Lellák and Kubíček, 1992; Ambrožová, 2003).

In the Czech Republic, there are five fish zones as Professor Frič designed (1888). The concept of fish zones was established to generalized similarities in the complex system of water continuum (Table 1). However, in many cases this concept cannot be applied and also, the exact boundaries cannot be defined (Kubečka, 2014).

Table 1 Selected characteristics of the fish zones (Adámek, 1995; Kubečka, 2014).

Fish zone	trout	grayling	barbel	bream	plaice
Stream type	mountain stream/brook	stream	river	river	river up to large stream
Bottom	rocky	rocky, gravelly	rocky, gravelly	gravelly, sandy, muddy	mostly sandy, muddy
Flow - rate	very fast	fast	fast	very fast	tide – dependent
Maximum temperature (°C)	12 – 18	18 – 20	18 – 22	20 – 25	22 – 30
Typical fish and lamprey species	Brown trout, Rainbow trout, Brook trout, Bullhead, European brook lamprey, chars, Eurasian minnow	Grayling, Rifle minnow, Eurasian minnow, leusiscus, Stone loach, Burbot, Brown trout	Barbel, Nase carp, Vimba bream, Danubian salmon, Common perch	Bream, Catfish, Pikeperch, Silver bream, Ruffe, Common perch	bream zone and brackish water species (mullets, plaices, Ruffe, gobies, sticklebacks)

The trout zone represents the highest parts and the brooks with the highest river slope, cleanest water, highest oxygenation, the lowest temperature and maximal water width 10 m (Kubečka, 2014). In the highest parts of the trout zone (over 500 m a. s. l.) are mainly present individuals of Brown trout or Bullhead, the abundance is maximally dozens or hundreds of individuals and the biomass is approximately dozens of kg. ha^{-1} at the most. In the lower parts with the smaller river slope and with pools, the numbers of abundance and biomass are much higher (10 000 individuals and over 500 kg. ha^{-1}). Typical aquatic vegetation are aquatic mosses, willow moss (*Fontinalis antipyretica*) and periphytic algae. Nowadays, a major problem of small streams is flow – rate fluctuations due to the climate change (Adámek, 1997; Kubečka, 2014). The grayling zone is mostly in greater brooks and streams of the foothills of mountains and highlands (400 – 600 m a. s. l.) where the river slope decreases. Water width is higher than 8 m and could be up to 15 m. Flow parts and also calm parts with shallow pools, and sediments are characteristic for this type of zone. The grayling zone shares a wide range of species with the trout and barbel zone. Fish abundance usually achieves to thousands of individuals and fish biomass could reach to hundreds of kg per hectare. Aquatic vegetation represents water macrophytes as *Batrachium* and *Callitriche* (Adámek, 1995; Kubečka, 2014). Due to these facts, Brdy PLA could be classified as the area of trout and grayling fish zone.

In the conditions of Czech Republic, all the water ecosystems and biotopes are affected by fish farming, which is the main threat for indigenous fish biodiversity on all levels (Lusk et al., 2000a; Lusk et al., 2002b). From the climatic side of view, Brdy PLA could be compared with Křivoklátsko PLA as the type of mountain conditions and temperature inversion is present in both PLAs. As Švátora et al. (2011) detected, there was confirmed occurrence of 28 fish species and 1 lamprey species of which almost all of 14 fish species confirmed in Brdy PLA were the same. From the geological side, Brdy Highlands are unique in contrast with other similar mountain complexes. Brdy Highlands consists of sedimentary rocks, sandstones and quartz conglomerates which are extremely poor in any other minerals than quartz, and which therefore produce infertile low – pH soils (more detailed description is in Chapter 1.4) (Cílek et al., 2015).

The occurrence of fishes and other water organisms in Brdy PLA is nowadays influenced and restricted mainly by low pH in some streams or their parts (AOPK, 2012). The main threat to ichthyofauna is fishery management on ponds. Frequent problems are high amount of mud in flows after the releasing of the ponds and the flow – rate fluctuations while manipulating with the water level of the pond (Padrťský pond with the low pH and high amount of toxic metals). Another threat to local ichthyofauna are predatory fishes as European perch (*Perca fluviatilis*), which are set into the ponds and water tanks and also massively reproduced there. As result, these predatory fishes restrict more important fish species directly in water tanks or penetrate to water flows and destroy local fish populations (e.g. Eurasian minnow (*Phoxinus phoxinus*)) (AOPK ČR, 2012).

1.2 Brdy PLA

Brdy Protected Landscape Area is a territory situated in the southwestern part of the Central Bohemian Region and in the eastern part of the Pilsen region of Czech Republic. The size of this area is 345 km^2. It is being structured into four zones depending on different status of protection (Figure 1). Its typical landscape structure presents mountainous wood landscape with minimal settlement, forestless parts, and natural communities. Characteristic natural and semi - natural communities for Brdy are purple moor and thistle meadows, heaths, peat-bogs, springs, wetlands, rock communities, forest communities with reliant rare protected species of fauna and flora. Inside the PLA are also protected paleontological sites, geological and geomorphological localities especially like stone sea, rock outcrops and frost weathering declared as a Special Area of Conservation (SAC) in Natura 2000 (Nature Conservation Agency of the Czech Republic, in Czech Agentura ochrany přírody a krajiny AOPK ČR, 2017).

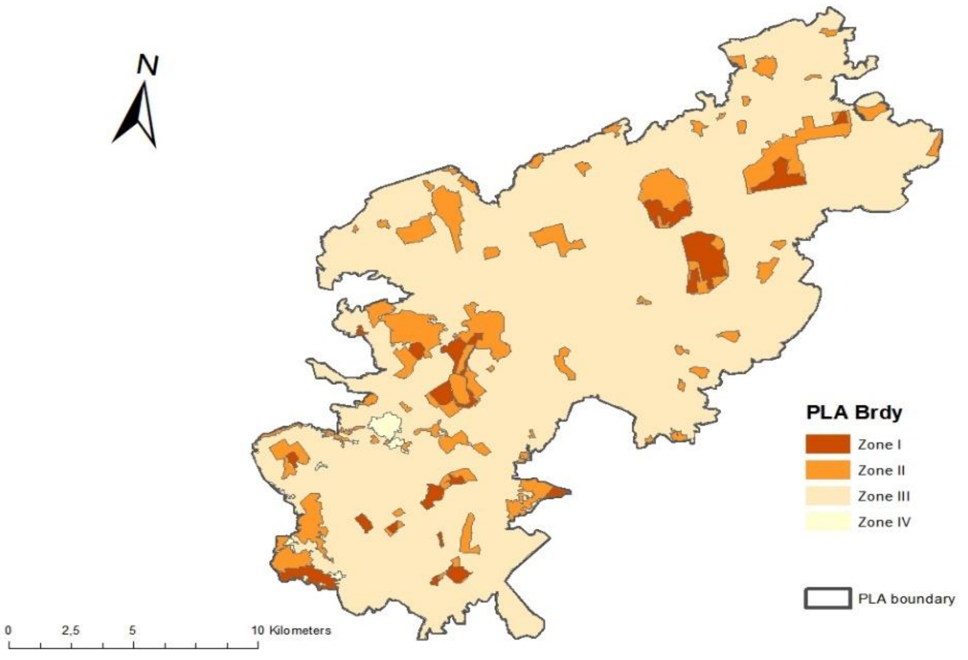

Figure 1 Zonation of Brdy PLA. Map was created in ArcGIS 10.2.2. (base map layer from AOPK ČR, 2017).

Brdy Protected Landscape Area was declared in January 2015. Small scale protected area (in Czech Máloplošně chráněná území) creates five Nature Reserves – Fajmanovy skály a Klenky, Getsemanka, Chynínské buky, Kokšín, Na skalách; two Natural Monuments – Hřebenec, Míšovské buky, Třemešný vrch and 16 SACs – Bradava, Brda, Felbabka, Hrachoviště, Ledný potok, Mešenský potok, Niva Kotelského potoka, Octárna, Ohrazenický potok, Padrťsko, Teslíny, Tok, Trokavecké louky, Třemšín a Hřebence, V Úličkách and Závišínský potok (Figure 2) (AOPK ČR, 2012 – 2013; AOPK ČR, 2017).

Figure 2 Brdy Protected Landscape Area with designed nature reserves, natural monuments and Special Areas of Conservation (Cílek et al., 2015).

1.3 History of Brdy PLA

Further historical human impacts in prehistorical times were probably relatively sparse due to a cold climate and poor soil and there were not many settlements in higher altitudes (AOPK ČR, 2017). However, the archaeological excavations proved that on the top of hill Plešivec existed hillforts from the Bronze Age (Cílek et al., 2015). More peremptory was medieval colonisation and thus logging and nowadays, crucial impact had modern forestry while creating spruce monocultures (AOPK ČR, 2017).

Apart from logging, Brdy area was rich in iron ore and precious metals. Due to this fact, this area has very distinctive mining past (Cílek et al., 2015).

From the first half of the 20th century a military base Brdy started to develop and opened a huge escapade of long - term changes for local inhabitants, fauna and flora in Brdy area (Cílek et al., 2015). In terms of nature protection, the great part of military activities in the military base Brdy had positive derogations to the local fauna and flora. Periodical fires, formation of pools due to the travel technology and the ammunition blasts, distortions of sods, creation of moorlands and heath on the impact surface were possible thanks to military activities. Furthermore, the harsh military handling with that space enabled creating and maintaining the valuable treeless environment (AOPK ČR, 2017).

Afterward the Ministry of Defence decided that the military base Brdy would be abolished during the year 2015 because of its redundancy and low military use (Pejšek, 2015). Consequently, the Brdy Protected Landscape Area was established on the 1st of January 2016 to protect the nature and landscape of the part of the area of Brdy Highlands (Vláda ČR, 2015).

1.4 Characteristics of Brdy PLA

Geological, pedological and climatic description of Brdy PLA

The Area of Brdy Protected Landscape Area belongs to the unit Brdy Highlands and to subunit Brdy. It has the character of isolated ragged highlands with height segmentation varying from 200 m to 300 m (Cílek et al., 2015) and with characteristic relief (Figure 3) (AOPK, 2012 – 2013). Only around the breakthrough of Litavka, it has a complexion of flat foothills with the topography up to 350 m. The basin surrounding the Padrťské ponds represents upland with topography 100 – 150 m (Cílek et al., 2015).

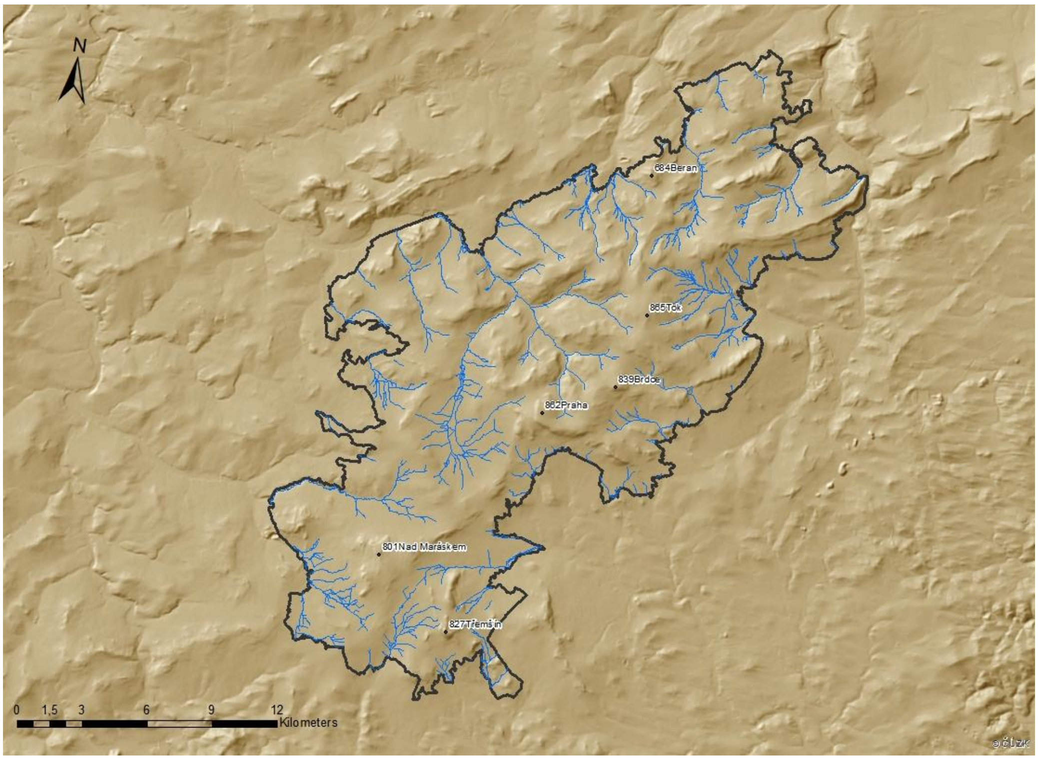

Figure 3 Geomorphological classification of Brdy PLA. Map was created in ArcGIS 10.2.2. (base map layer from ČÚZK, 2017).

The origin of highest parts of Brdy Highlands is mostly from the extremely acidic Paleozoic pudding – stones, Cambrian quartzites, flints and hard sandstone creating rock stages, inselbergs or monadnocks and opened boulder screes on the foot (Cílek et al., 2015; AOPK ČR, 2017; Česká geologická služba, 2017). Also, geological base was formed by rocks of early Paleozoic in this area (Cílek et al., 2015; Česká geologická služba, 2017). On the western part of Padrťský ponds banks are also presented Proterozoic flints (Česká geologická služba, 2017). Rounded peaks with wide protracted saddles sequestered by widely opened ravine valleys mostly without typical floodplain because their bottoms are covered by boulder rubble (Cílek et al., 2015). Brdy Highlands represent the greatest coherent area formed by such composition of rocks in Czech Republic. This fact distinguishes them from border mountainous complexes which are usually built by crystalline basement (AOPK ČR, 2017). Range of altitude in the Brdy PLA varies from 600 to almost 900 metres above sea level with the major highest peaks which are Tok at 865 m a.s.l., Praha at 862 m a.s.l. and Třemšín at 827 m a.s.l. (ČÚZK, 2017). Regarding the climatic aspect, there is a great disparity between higher altitude and lower lying areas. Due to this big elevation span, the character of the climate is cold, harsh, and wet in the mountain part and therefore warmer and drier in lower or lower marginal parts (AOPK ČR, 2017) and enables to classify the highest part of the Brdy Highlands as mountainous environment according to UN Environmental Programme´s definition (Cílek et al., 2015). Likewise, from the pedological side of the view, the constitution of Brdy are mostly very dominant unsaturated cambisols and partly gley soils. On the edges occurs saturated cambisols and pseudogleys (Český geologický úřad, 2017). Moreover, pedologically are Brdy different from the surrounding parts and even from the greater landscape units as Křivoklátsko PLA and Český kras PLA (AOPK ČR, 2017). Average precipitation in higher altitudes is approximately 800 millimetres per year in comparison with lower altitudes where the precipitation is on average approximately 500 millimetres. Lower parts belong to slightly warm to wet climatic area with average year temperature 7° C and the highest central parts are classified as cold and humid climatic area with average year temperature 5.5° C. The average annual precipitation situation is possibly comparable to Šumava National Park for instance (AOPK ČR, 2012).

Flora and Fauna

Firstly, from the phytogeographical side of view the Brdy PLA could be classify as part of the Orepophyticum Massivi bohemici (Skalický, 1988) which represents mostly mountainous areas with cryophilic vegetation and marginally as part of the Mesophyticum Massivi bohemici (Skalický, 1988) creating a transformation between thermophilic and cryophilic vegetation (Skalický, 1988; CzechInspire, 2013). For the oreophyticum are typical mountain spruce forests (*Calamagrostio villosae – Piceetum*, *Bazzanio – Piceetum*), sphagnum spruce forests (*Sphagno – Piceetum*), sphagnum birch forest (*Betuletum pubescentis*), then also wellsprings, peat bogs, bogs and wet meadows. Mountain vegetation is not very widely distributed on the top of the hills and the ridges because of dry and non - beneficial soil. On the other hand, the mountain vegetation is widespread in humic forests, in peat bogs, around streams and in cold valleys. The most important phenomena in Brdy highlands classify them to mountain parts of Czech Republic is the presence of peat bogs (AOPK ČR, 2012 - 2013). Forestry had a huge impact on vegetation. Influence of local forestry and the presence of spruce monocultures resulted in decrease of species diversity. In the past, the forest species diversity was richer, but nowadays the spruce monocultures dominate and the forests

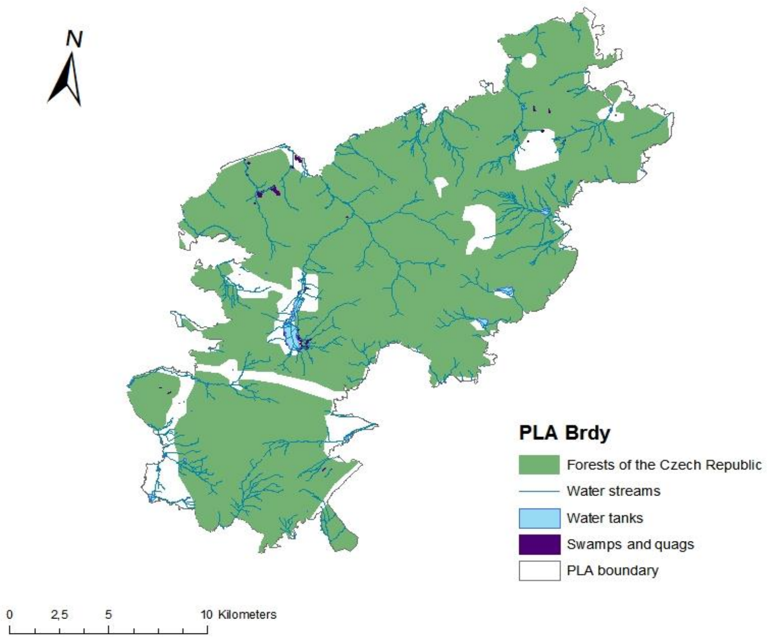

Figure 4 Forest coverage and hydrologic site of Brdy PLA. Map was created in ArcGis 10.2.2. (base map layer from ArcČR 500, 2015).

with original character (e.g. beechwoods) are present only partly (Domin, 1926; AOPK ČR, 2012). Forest coverage of Brdy PLA is shown on Figure 4. In general, and in the zoogeographic term, information about fauna and flora is still lacking owing to the long existence of the military base which influenced the small number of adequate analyses (Cílek et al., 2015). Since Brdy Highlands are large wooded mountains in central Bohemia, therefore it is also important refugia in surrounding culturally managed landscape Representatives of phylum Mollusca, class Arachnida, order Coleoptera, order Lepidoptera, order Diptera, subphylum Crustacea (species Stone crayfish (*Austropotamobius torrentium*), Noble crayfish (*Astacus astacus*), Slender – clawed crayfish (*Astacus leptodactylus*), Tadpole shrimp (*Triops cancriformis*)), superclass Cyclostomata (*Lampetra planeri*), superclass Osteichthyes, class Amphibia and class Reptilia (app. 14 species living in Czech Republic), class Aves (well researched and great species diversity), class Mammalia (high species diversity and also presence of alien species and their influence on indigenous species) are present in Brdy PLA (AOPK ČR, 2012; AOPK ČR, 2012 - 2013).

Hydrography of Brdy PLA

Brdy PLA contains a rich hydrological network with clear water and mostly natural stream beds or regulated stream beds, river basins and banks (Figure 4). Brdy waters are also important source and water reservoir of fine drinking water for surrounding inhabited areas. Brdy PLA is mostly dewatered by the streams Litavka and its inflows and by Klabava into the river Berounka. Only a small part of waters is dewatered into the Vltava (AOPK ČR, 2017). Litavka is 54.93 km long flow which springs in the Brdy Highlands at altitude 737 metres a. s. l. between the highest peaks Tok (865 metres a. s. l.) and Praha (862 metres a. s. l.). The biggest inflow is Červený brook (29.11 km length) and there are also two water tanks Pilská (20.54 ha) and Láz (15.01 ha). Klabava is 51.22 km long flow which springs under the peak Praha at latitude 760.29 metres a. s. l. The biggest inflow is Holoubkovský brook (23.54 km) which is out of Brdy PLA and there are one water tank Hořejší padrťský pond (78.80 ha) in Brdy PLA (Dibavod, 2017). The stream network which drainage the higher and slanting parts tends to reduce flow and get dry in the seasons with lack of precipitation from August to winter months. Highest water flow is in March when is the peak of spring snow melting. Prevailing hydro - morphological feature in this area is straight and slightly undulating streams (AOPK ČR. 2012). In some flows or their parts, the occurrence of species is decreased by low pH and poor soils (Fischer, 2012).

Ichthyofauna of Brdy PLA

Fish assemblages in Brdy streams were kept mainly thanks to almost complete absence of piscatorial management in former military base through the years (Cílek et al., 2015). In these waters a spontaneously reproducing population of Brown trout (*Salmo trutta*) is present. Then, there is significant occurrence of European brook lamprey (*Lampetra planeri*) and Bullhead (*Cottus gobio*) pursuant on, several SCI (Sites of Community Importance) were defined for their protection (Závišínský brook, Ledný brook, Ohrazenický brook, Octárna, Kotelský brook, Brda). Further, there is occurrence of European minnow (*Phoxinus phoxinus*) and the population in the past was numerous, but currently it is decimated by the pressure of European perches

(*Perca fluviatilis*) which escape from the ponds and water tanks (Octárna, Pstruhový pond, etc.). Other present species are common representatives of trout, grayling and barbel zone, thus Chub (*Leuciscus cephalus*), Gudgeon (*Gobio gobio*), Roach (*Rutilus rutilus*), Stone loach (*Barbatula barbatula*) and European perch (*Perca fluviatilis*). Burbot (*Lota lota*), which used to occur naturally there, is nowadays artificially set into the stream network. Some of the fish species present in this area are not indigenous and were set into the streams. It is mainly Common carp (*Cyprinus carpio*), Crucian carp (*Carassius carassius*), Tench (*Tinca tinca*), Belica (*Leucaspius delineatus*), Freshwater bream (*Abramis brama*), Northern pike (*Esox lucius*), European eel (*Anguilla anguilla*), Rudd (*Scardinius erythrophtalmus*) and Brook trout (*Salvelinus fontinalis*) (Lusk et al., 2010; AOPK ČR, 2012). Then, Rainbow trout (*Oncorhynchus mykkis*), Pike – perch (*Sander lucioperca*) and indigenous species Grass carp (Ctenopharyngodon idella) are set into the ponds and water tanks (AOPK ČR, 2012)

1.5 Fish species in focus in Brdy PLA

Several protected fish species apart from the common species not determined as protected among the Red List (Hanel and Lusk, 2003; Lusk et al., 2004) were found in the Brdy Protected Landscape Area.

European brook lamprey (*Lampetra planeri*, Bloch, 1784) (Figure 5) is considered as threatened – endangered (EN) species in Czech Republic (Hanel and Lusk, 2003). It is a fish vertebrate from the order Petromyzontiformes, class Cephalaspidomorphi, superclass Cyclostomata (Renaud, 2011). The species is freshwater, demersal, potamodromous (Riede, 2004) with wide range of occurrence in Europe - streams and rivers of northern and north eastern Europe from Ireland, Great Britain to Russia and on south in southern France, Italy, Albany and Dalmatia, not detected in the drainage areas of Black sea (Freyhof, 2011b). According to Kottelat and Freyhof (2007), adults are found in the lowland, piedmont and montane zone in clear, well oxygenated brooks. Non - parasitic on other fish species (Maitland, 2003). The length at first maturity is 12.5 cm, its size varies from 16 – 20.5 cm (Verreycken et al., 2011) and the maximum reported age was 7 years (Hardisty, 1986). Apart from other fishy vertebrates, lampreys have a sucking circular disc, weakly developed fins and instead of gills, they do have seven respiratory holes (Kelly and King, 2001).

Larvae of European brook lampreys are called ammocoetes and live hidden in the detritus - rich sands or oozy, clay sediments for 3 – 5 years (Kottelat and Freyhof,

Figure 5 European brook lamprey with detailed circular sucking disc (photo by T. Caska, 2016).

2007). They prey on small invertebrate organisms and algae. After transforming to adult, eyes and teeth are developing but the digestive tract atrophies (Maitland, 2003). Hanel et al. (2003), and Hanel and Andreska (2006) have reported that larvae of this species can serve as bio-indicators for long - term high quality local environment.

Into the group of threatened - vulnerable species (VU) belong Eurasian minnow (*Phoxinus phoxinus*, Linnaeus, 1758), Burbot (*Lota lota*, Linnaeus 1758) and Bullhead (*Cottus gobio*, Linnaeus 1758) (Hanel and Lusk, 2003).

Eurasian minnow (*Phoxinus phoxinus*) (Figure 6) is small conformable in flock living fish (Spillman, 1961) out of order Cypriniformes, class Actinopterygii (Nelson, 2006; Strange and Mayden, 2009). Commonly lives in clear well oxygenated flowing waters and lakes with gravelly bottom nearby the water surface and very often appears with salmonid fishes (Kottelat and Freyhof, 2007; Terofal, 1984). It is distributed in Eurasia (Terofal, 1984; Freyhof and Kottelat, 2008). Length at first maturity varies from 5 - 5.8 cm and the common length varies from 7 – 10 cm (Muus and Dahlström, 1968) while the females can grow up to 10 cm (Terofal, 1984). Kottelat and Freyhof (2007) claimed that the maximum reported age was 11 years. The diet consists of petty demersal organisms, insects floating on water surface, algae, molluscs and crustaceans (Billard, 1997). Both sexes have spawning rash during spawning (Terofal, 1984).

Burbot (*Lota lota*) (Figure 6) belongs to order Gadiformes and class Actinopterygii (Cohen et al., 1990; Nelson, 2006). It is a crepuscular and nocturnal species and the only deputy of freshwater gadoids (Terofal, 1984; Keith et al., 1992). Burbot also lives in brackish waters and is demersal and potamodromous (Kottelat and Freyhof, 2007). The area of distribution extends from Western Europe to basin of Amur (Terofal, 1984) and is circumarctic in freshwater (Cohen et al., 1990). Distinguishing feature of this species from other freshwater fishes in Europe, is one central barbel on lower chin (Figure 6) (Morrow, 1980).

Figure 6 Illustrating photos of a) Eurasian minnow, b) Burbot, c) detail of single barbel on the chin (photo by A. Ťuláková, 2016).

Bullhead (*Cottus gobio*) (Figure 7) lives in shallow, freshwater, brackish and well oxygenated waters, also in rapidly running streams of trout zones and in shore zones of Alpine lakes up to 2,200 metres above sea level (Terofal, 1984; Kottelat and Freyhof, 2007). It has wide distribution in the west, central and east Europe (Terofal, 1984; Freyhof, 2011b). This species belongs to orded Scorpaeniformes and to class Actinopterygii (Nelson, 2006). Bullhead is also demersal and living under the stones or in the sandy and gravel bottom (Terofal, 1984; Kottelat and Freyhof, 2007) and moreover it is potamodromous and present in pH range 7 – 7.5 (Riede, 2004). Body is often appearing naked and scaleless (Nelson, 2006). Body length at first mature is 4.2 cm and the maximum body length is approximately 18 cm (Muus and Dahlström, 1968; Terofal, 1984). The highest reported age was 10 years (Seppälä et al., 2007). This species misses gas bladder in their internal system (Terofal, 1984). It feeds on small organisms and invertebrates such as insect larvae or crustaceans (Terofal, 1984; Freyhof et al., 2005).

Figure 7 Ilustrating photos of Bullhead (photo by T. Caska and A. Ťuláková, 2016).

Brown trout (*Salmo trutta*, Linnaeus, 1785) (Figure 8) is least concern species (Freyhof, 2011c), widespread in cold well oxygenated waters and lakes with stone and gravelly bottom from Spain over whole Europe to Ural (Svetovidov. 1984; Freyhof, 2011c) out of the order Salmoniformes and class Actinopterygii (Nelson, 2006). This species lives in freshwater, marine and brackish waters (Riede, 2004) and preys on small invertebrate organisms, insects moving on the water surface, very often preying on larvae of caddisflies and elder individuals also on other small fish and tadpoles (Cadwallader and Backhouse, 1983; Terofal, 1984). Length varies from 50 cm to 140 cm (Bauchot, 1987) and the highest reported age was 38 years (Svalastog, 1991).

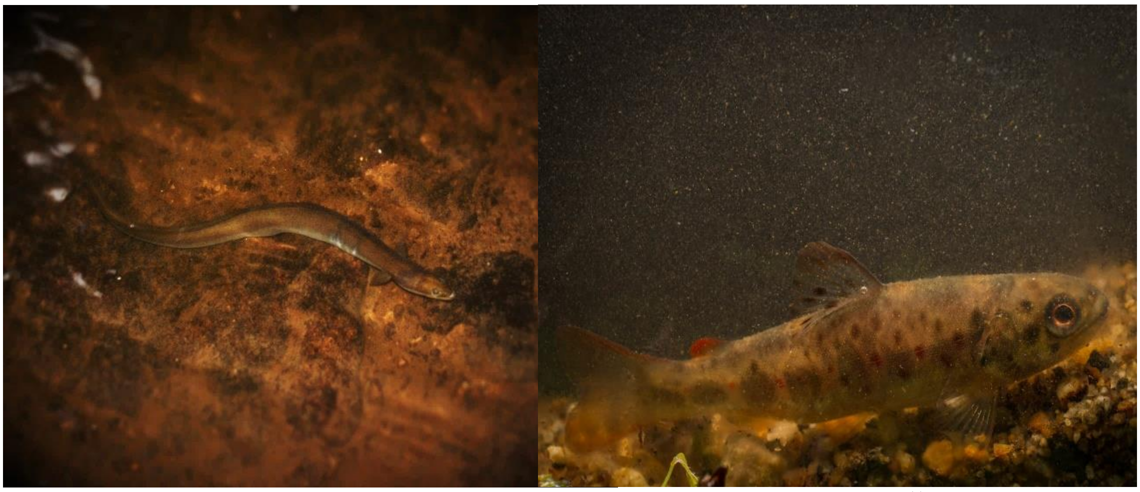

Figure 8 Ilustrating photos of a) European eel (photo by A. Ťuláková, 2016) and b) Brown trout (photo by T. Caska, 2016).

Other species occurring during research in Brdy PLA and in this diploma thesis are namely Gudgeon (*Gobio gobio*), European perch (*Perca fluviatilis*), Northern pike (*Esox lucius*), Common roach (*Rutilus rutilus*), Tench (*Tinca tinca*), Stone loach (*Barbatula barbatula*), European eel (*Anguilla anguilla*), Brook trout (*Salvelinus fontinalis*), Rudd (*Scardinius erythrophtalmus*), Tiger trout (hybrid Brook trout x Brown trout).

2 Aims of the Thesis

The aim of the thesis was to determine the fish species diversity, fish abundance, fish biomass and age structure of selected species from fish scales of the ichthyofauna in the context of different environmental and anthropogenic variables in the Brdy Protected Landscape Area in Central Bohemia. Particularly, investigation was focused on questions how fish abundance, species diversity and biomass were related to the measured parameters pH, conductivity, water width and to the qualitative parameters type of the stream bed (natural/regulated), presence/absence of aquatic vegetation and presence/absence of pools. Further aim was to compare populations of certain fish species in 2000 and in 2016.

3 Materials and Methods

3.1 Characteristics of water profiles

Actual water sources in the investigated area Brdy PLA were mapped for determining sampling sites i.e. localities. Sampling sites consisted of at least 2 – 4 representative hunting profiles in accordance with the length of the water source (Figure 9). Standard length determined for each hunting profile was approximately 100 meters apart from localities where it was impossible to conduct the entire hunting profile e.g. due to water shortage and therefore the length was adjusted. All the profiles were described and main characteristics of water profiles used in analyses see in Table 2. Qualitative parameters are type of the stream bed which represents either naturally shaped bed without any human interference or regulated, channelized or somehow modified water beds. Pools, which were described with maximal depth to 1.6 metres. Also, aquatic vegetation, which was formed by water mosses, willow moss (*Fontinalis antipyretica*), macrophytes as *Batrachium* and *Callitriche.*

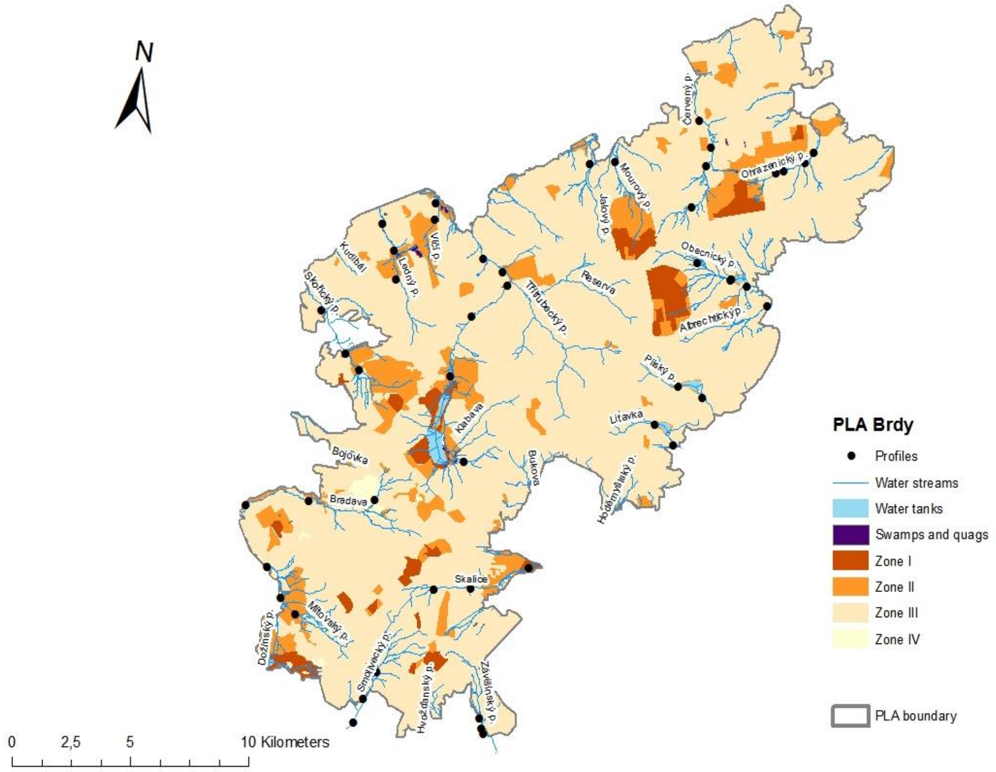

Figure 9 Map of realised water profiles within Brdy PLA, hydrologic site and zonation of Brdy PLA. Map was created in ArcGis 10.2.2. (base map layer from AOPK ČR, 2017).

Table 2 Characteristics of water profiles.

ID	Profile	Natural / Regulated	Pools	Aquatic vegetation	Width of water (m)
1	Albrechtský brook	N	yes	no	1.2
2	Inflow – Hořejší Padrťský pond	R	yes	no	1
3	Bradava Bílý brook 1	N	no	no	0.7
4	Bradava 2	R	yes	yes	3.5
5	Bradava 3	N	yes	yes	7
6	Červený brook 1	R	no	no	1.5
7	Červený brook 2	N	yes	no	2
8	Červený brook 3	N	yes	no	2.5
9	Červený brook 4	N	yes	no	3.5
10	Jalový brook	N	yes	no	2.5
11	Klabava 1	N	yes	yes	1.8
12	Klabava 2	N	no	yes	4
13	Klabava 3	R	no	no	4
14	Klabava 4	N	no	no	6
15	Klabava 5	R	no	no	5
16	Kotelský brook 1	N	yes	no	1
17	Kotelský brook 2	N	yes	no	2.5
18	Kotelský brook 3	N	yes	yes	2
19	Ledný brook 1	N	yes	no	2.5
20	Ledný brook 2	N	yes	yes	2.5
21	Ledný brook 3	N	yes	yes	3
22	Litavka 1	N	yes	no	1.5
23	Litavka 2	R	no	yes	2.5
24	Mitovský brook 1	R	yes	yes	2.5
25	Mitovský brook 2	R	yes	yes	4
26	Mitovský brook 3	R	yes	yes	3.5
27	Mourový brook	N	yes	no	2
28	Obecnický brook 1	N	no	no	2.5
29	Obecnický brook 2	N	yes	no	2.5
30	Obecnický brook 3	R	yes	no	4
31	Inflow Octárna	N	no	no	0.5
32	Pilský brook 1	R	no	no	1.5
33	Pilský brook 2	R	yes	no	1.2
34	Pstruhový – Ohrazenický brook 1	N	yes	no	1
35	Pstruhový – Ohrazenický brook 2	N	yes	no	1.8
36	Pstruhový – Ohrazenický brook 3	R	yes	no	1.5
37	Pstruhový – Ohrazenický brook 4	N	yes	no	3
38	Skořický brook 1	N	yes	yes	2.5
39	Skořický brook 2	N	yes	no	3
40	Skořický brook 3	N	no	yes	3
41	Smolivecký brook 1	N	yes	no	2
42	Smolivecký brook 2	N	yes	yes	2
43	Smolivecký brook 3	N	yes	yes	4
44	Vlčí brook 1	R	yes	no	2
45	Vlčí brook 2 (75m)	R	yes	no	1.8
46	Závišínský brook 1	R	yes	yes	1
47	Závišínský brook 2	R	yes	yes	1.2
48	Závišínský brook 3	N	yes	no	2.5

3.2 Data collection

The sample collection and measuring in the field were conducted from July to October 2016.

3.3.1 Methods of fish capture and measurements

Ichthyological survey was done by using the method of standard electrofishing (Kestemont et Goffaux, 2002). Therefore, it was used the battery aggregate LENA (pulse current 60 – 90 Hz) for electrofishing. Only licensed person used the battery aggregate LENA. Furthermore, it was applied the system of continual hunt and the method of fording (Vlach, 2008). All possible biases were avoided to ensure maximum data quality by operators fishing efforts and selection of sampled habitats (Tomanova et al., 2013). Catching of fish was always carried out by hunting group of 2 – 7 people. The hunt always started from the down part of the profile and then the fishing squad went against the current to the upper part of the profile. The hunting was proceeded from the banks in hardly reachable places. All, of the hunted fish were taken from the water by the members of the fishing squad and were kept in the well oxygenated vessels apart from the battery aggregate with well oxygenated water. This process was always done twice, meaning two hunts thus the second hunt was always conducted immediately after the deflation of roiling sediment. After measuring, weighing and taking scales, fish were again released into the water in the most suitable part of the profile. Another part of the survey focusing on European brook lampreys was realised pursuant to the methodics for this species (Dušek, 2007). According to Dušek (2007), the method consists in evicting the larval stages of European brook lampreys = the ammocoetes from the deep fine grained sediments by using the battery aggregate. The presence of the ammocoetes and the brook lampreys was checked in all, of the potentially suitable sediment parts within the profiles and the caught individuals were kept separately from other hunted fishes.

Other technical facilities used for the ichthyological survey was special equipment as vessels, several types of landing nets, tape – measure for the width and length of the profiles, special scale with range 50 cm, weighing scale with the accuracy ± 0.5g, tweezers for taking scales and clean and disinfected fishing waders or knee – boots.

In the ichthyological survey were measured physical and chemical water parameters of the majority of the researched water streams such as pH, conductivity, TDS and temperature. For measuring these chemical and physical water parameters a special combined measuring meter Extech EC500 pH/ Conductivity/ Total Dissolved Solids (TDS)/ Salinity meter (ExStik company, USA) was used. The range of pH was from 0.00 to 14.00 with the accuracy ± 0.01. In case of conductivity ranges, there were three combined spans 0 to 199.9 $\mu S.cm^{-1}$, 200 to 1999 $\mu S.cm^{-1}$ and 2.00 to 19.99 $mS.cm^{-1}$ with the accuracy ± 2 % full scale. According to the HM Digital Company (2012), total dissolved solids (TDS) are the total number of ions, including minerals, salts or metals dissolved in the water. TDS ranges were correlated with the conductivity ranges and had also three combined spans 0 to 99.9 mg. L^{-1}, 100 to 999 mg. L^{-1} and 1.00 to 9.99 g. L^{-1} with accuracy ± 2 % full scale. As for the temperature range, it was from -5.0°C to 90.0°C, with the accuracy ± 1 °C from -5 to 50 °C and ± 3 °C from 50 to 90 °C.

3.3.2 Scale´s sample collection and fish age determination

Age structure of four fish species - *Salmo trutta, Phoxinus phoxinus, Perca fluviatilis, Rutilus, rutilus* was analysed from dataset of sufficient amount. Scales were taken from 55 European perches (*Perca fluviatilis*), 41 Eurasian minnows (*Phoxinus phoxinus*), 42 roaches (*Rutilus rutilus*) and 289 brown trouts (*Salmo trutta*) altogether from 27 profiles and 13 localities. In addition, the rest of the researched species were rather in low numbers, without scales or there was not any possibility how to take the scales e.g. as for the European eel. The method of collection and determination of age from the fish scales was done pursuant to Pivnička (2002).

Nowadays besides the fish scales, the bony elements such as operculum, cleithrum, vertebrae or auditory ossicles - otoliths are mostly used for determining of the fish age. Due to the changing conditions, temperature or conditions of individuals, certain changes are occurring on those structures leading to layering of particular plies and creating the sclerites and annuluses (Figure 10). The fish age is possible to detect out of these characteristics (Pivnička, 2002).

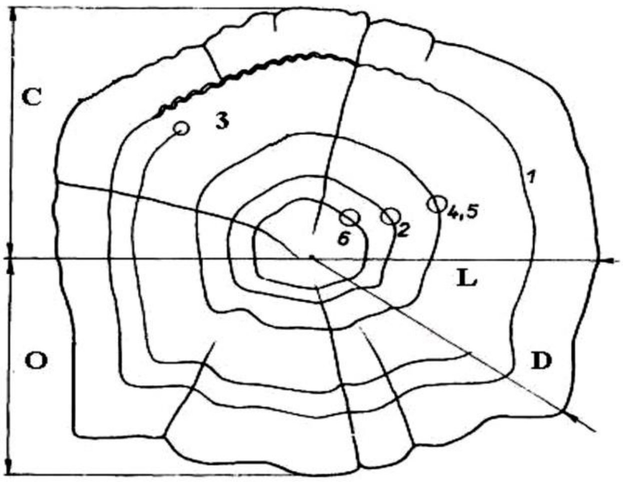

Figure 10 Illustrating picture of fish scale schema of roach (*Rutilus rutilus*) and particular types of annuluses (Pivnička, 2002).

The determining of the age based on the scales of the collected fishes was accomplished in the Biology Center CAS in České Budějovice under control of the consultant RNDr. Petr Blabolil. Determination itself was done via the scale reader Meoflex MI 21P (Indus company, USA) and by using the standard 20 cm ruler, tweezers and clear straightened scales.

3.3.3 Data treatment and analyses

Basic statistical independent unit used in the analyses was profile and unless stated otherwise, the rest analyses were related to stream localities. Several parameters as total fish abundance and fish biomass were calculated. Total fish abundance per hectare was calculated as total number of individuals on profile divided by the size of the profile (in m^2) and multiplied by 10 000 (to get hectares). Total fish biomass per hectare for each profile was calculated as sum of total weight of fish (in kg) divided by size of profile (in m^2) and finally multiplied by 10 000 (to get hectares). Data were analysed by standard statistical methods according to collected data predominantly in Statistica 13.2 software (Dell Inc., USA).

Environmental characteristics of water

All quantitative physical and chemical parameters (conductivity, TDS, pH, temperature) and also all qualitative parameters (type of stream bed, presence of pools, presence of aquatic vegetation) were described via descriptive statistics. No testing with temperature was proceeded due to the fact, that the research was conducted in different seasonal conditions, therefore temperature was not relevant parameter.

Species diversity

Species diversity and total number of species express the same information in this thesis. Dataset had a normal distribution which was proved by Kolmogorov – Smirnov test (K-S d = 0.15, $p > 20$). Simple linear regression was used for comparing the dataset of the relationship between total number of species and pH, conductivity and width of water. Environmental parameters (type of stream bed, aquatic vegetation and presence of pools) were statistically compared with species diversity via ANOVA test. The relationship between the type of the stream bed, presence of aquatic vegetation and the species diversity was also subsequently tested by Student´s t-test.

Fish abundance

The dataset of total abundance of species on profile per hectare do not have normal distribution. For evaluation was use Kolmogorov – Smirnov test (K – S d = 0.26, $p < 0.01$). Reflecting this fact, it was necessary to make log - transformation of the data and repeated the Kolmogorov – Smirnov test (K – S d = 0.14, $p > 0.2$). Next step was to use the main - effects ANOVA for three qualitative parameters – natural or regulated streams, the presence of aquatic vegetation, the presence of pools in relationship with the total abundance of species per hectare. As for the quantitative parameters (pH, conductivity and water width), it was used simple linear regression.

Fish biomass

Data had normal distribution proved by the Kolmogorov-Smirnov test (K-S d= 0.12, $p > 0.20$). The relationship between total biomass ($kg.ha^{-1}$) and total number of individuals was described using linear regression. The quantitative parameters (pH, conductivity and water width) were expressed using linear regression model. For the description of the relationship between natural or regulated streams, presence of aquatic vegetation or not, presence of pools and total biomass was use factorial ANOVA test.

Fish age

Complete dataset contained determined age records from 289 individuals of Brown trout (*Salmo trutta*) from 12 localities, 41 individuals of Eurasian minnow (*Phoxinus phoxinus*) from two localities, 55 individuals of European perch (*Perca fluviatilis*) from five localities, 42 individuals of Common roach (*Rutilus rutilus*) from 4 localities. 0+ to 4+ means age groups of this year fishes to four years old fishes.

Other treatments

Dataset of European brook Lamprey (*Lampetra planeri*) was expressed in graphic charts and table. Also, the dataset of numbers of certain species on selected localities from 2000 was shown on the charts together with records from this study.

4 Results

4.1 Environmental characteristics of water profiles

Results for measured physical and chemical parameters on 47 surveyed profiles were following: **average pH** was 7.4 (± 0.1 SE) ranging from 6.1 to 8.2; **average total dissolved solids (**TDS) was 89.7 mg. L^{-1} (± 6.0 SE), ranging from 26 mg. L^{-1} to 204 mg. L^{-1}, **average conductivity** was 112 μS. cm^{-1}, ranging from minimum 31 $\mu S.cm^{-1}$ to maximum 256 μS. cm^{-1} (± 7.5 SE) and **average temperature** was 12.7 °C, ranging from 8 °C to 16.4 °C (± 0.3 SE). All values for profiles are given in the Table 4. The conductivity, TDS and pH were mutually correlated (Table 3) from which, the correlation between conductivity and TDS was very strong regarding the fact that TDS measurements were based on recalculation from conductivity. Also, average **water width** was 2.5 m (± 0.2 SE) with the minimum 0.5 m and maximum 7 m.

As for the **qualitative parameters**, out of all 48 profiles were 31 with natural stream bed and 17 were regulated. The description of the **presence of the aquatic vegetation** in streams i.e. whether the aquatic vegetation is present in the stream or not, showed that it is present in 17 cases and none in 31 cases. In case of **the presence of the pools**, there were some in 37 cases and there were none in 11 cases.

Table 3 Correlation between quantitative physical and chemical variables. Statistically significant correlations ($p < 0.05$) are indicated in bold.

N = 47	Conductivity (μS.cm-1)	pH	TDS (mg. L^{-1})
Conductivity ($\mu S.cm^{-1}$)	1.00	**0.64**	**0.99**
pH	**0.64**	1.00	**0.63**
TDS (mg. L^{-1})	**0.99**	**0.63**	1.00

Table 4 Results of measurements of physical and chemical environmental parameters (TDS = Total Dissolved Solids).

ID	Profile	Conductivity (µS. cm^{-1})	pH	TDS* (mg. L^{-1})	t (°C)
1	Albrechtský brook	124.0	6.99	102.4	14.0
2	Inflow Hořejší Padrťský pond	100.5	7.65	81.0	13.0
3	Bradava Bílý brook 1	81.5	7.43	61.3	8.0
4	Bradava 2	123.4	7.25	120.1	9.0
5	Bradava 3	150.0	7.33	120.2	9.0
6	Červený brook 1	41.8	6.09	34.2	15.2
7	Červený brook 2	58.2	6.99	39.2	14.9
8	Červený brook 3	62.3	7.15	49.5	14.1
9	Červený brook 4	71.0	7.32	58.0	15.5
10	Jalový brook	36.5	7.15	29.6	14.9
11	Klabava 1	125.0	7.20	98.8	15.2
12	Klabava 2	113.8	7.50	91.7	16.4
13	Klabava 3	116.0	7.70	87.0	16.0
14	Klabava 4	103.0	7.70	81.4	15.3
15	Klabava 5	105.0	7.70	84.8	15.7
16	Kotelský brook 1	49.8	6.68	40.0	12.1
17	Kotelský brook 2	88.9	7.38	67.5	11.9
18	Kotelský brook 3	134.5	7.32	106.5	13.8
19	Ledný brook 1	130.4	7.60	102.0	14.3
20	Ledný brook 2	147.4	8.05	118.5	14.6
21	Ledný brook 3	164.8	8.03	132.6	14.7
22	Litavka 1	51.1	7.65	40.1	11.6
23	Litavka 2	77.4	7.26	63.5	11.7
24	Mitovský brook 1	61.0	6.77	54.5	8.9
25	Mitovský brook 2	145.0	7.28	118.2	9.8
26	Mitovský brook 3	169.5	7.33	130.5	9.7
27	Mourový brook	62.0	7.35	41.3	14.7
28	Obecnický brook 1	not registered			
29	Obecnický brook 2	73.5	7.58	57.6	10.6
30	Obecnický brook 3	110.6	7.16	89.5	13.5
31	Inflow Octárna	121.6	7.40	98.0	11.2
32	Pilský brook 1	31.3	6.90	26.2	11.8
33	Pilský brook 2	79.5	6.90	60.7	13.2
34	Pstruhový - Ohrazenický brook 1	51.2	7.29	35.6	12.9
35	Pstruhový - Ohrazenický brook 2	82.7	7.12	70.1	14.9
36	Pstruhový - Ohrazenický brook 3	105.0	7.30	83.7	13.9
37	Pstruhový - Ohrazenický brook 4	109.3	7.47	90.0	14.2
38	Skořický brook 1	246.0	7.80	198.0	13.8
39	Skořický brook 2	167.2	7.68	133.5	13.1
40	Skořický brook 3	157.5	7.58	125.5	13.1
41	Smolivecký brook 1	106.5	7.11	82.5	9.8
42	Smolivecký brook 2	127.4	7.28	102.8	9.3
43	Smolivecký brook 3	106.5	7.49	89.5	10.0
44	Vlčí brook 1	256.0	8.16	204.0	13.4
45	Vlčí brook 2 (75 m profile)	250.0	8.00	201.0	15.3
46	Závišínský brook 1	126.8	7.32	94.8	9.8
47	Závišínský brook 2	118.9	7.4	98.9	10.1
48	Závišínský brook 3	149.5	7.16	118.2	10.3

4.2 Fish species diversity

Out of total number of 48 surveyed profiles were 5 % of six species (European brook lamprey included), 10 % of five species, 13 % of four species, 19 % of three species, 21 % of two species, 19 % monospecific and 13 % without any fish species.

Average number of fish species and one lamprey species on 48 investigated water profiles was 3 (± 0.3 SE) species and median was 2 species on profile, respectively, ranging from 2 in 11 profiles to 6 in 3 profiles (see Table 5 and Table 6). The most frequent species was Brown trout in total on 13 localities, followed by Common perch on 7 localities and Bullhead on 6 localities.

The pH and conductivity of water had positive, but relatively weak effects on fish species diversity (Figure 11 and 12). The species diversity increased with the width of water profile (Figure 13).

Results for relationship of fish species diversity in streams with and without pools and also for natural and regulated stream beds were not significant (pools: $F_{(1, 45)} = 1.1$, $p = 0.3$; stream bed type: $F_{(1, 45)} = 0.008$, $p = 0.9$). Then, the fish species diversity was significantly higher when aquatic vegetation was present ($F_{(1, 45)} = 5.3$, $p = 0.03$). In streams with aquatic vegetation (N = 17), there was on average 4 fish species (± 0.3 SE), while in streams without aquatic vegetation (N=30), there was on average 3 fish species (±0.3 SE). Figure 14 showed relationship between the three qualitative parameters and fish species diversity, however statistical results for this analysis were not significant.

The analysis (Figure 15) showed that in streams with natural bed the number of species was significantly higher when there was also the aquatic vegetation than without it (Student’s t-test: $t = 2.4$, $df = 25$, $p = 0.02$), while in streams with regulated bed, the species diversity was not affected by presence or absence of aquatic vegetation (Student’s t-test: $t = 0.3$, $df = 13$, $p = 0.78$).

Table 5 Total numbers of fish species, fish abundance per hectare and total biomass per hectare.

	Species	***Salmo trutta***	***Cottus gobio***	***Perca fluviatilis***	***Rutilus rutilus***	***Phoxinus phoxinus***	***Lota lota***	***Barbatula barbatula***	***Esox lucius***	***Anguilla anguilla***	***Gobio gobio***	***Tinca tinca***	***Salvelinus fontinalis***	***Scardinius erythrophtalmus***	**Tiger trout**	**Number of species**	**Total abundance (per ha^{-1})**	**Total biomass (kg. ha^{-1})**
ID	**Locality**																	
1	Albrechtský b.	1														1	83	4
2	Inflow Hořejší Padrťský pond																	
3	Bradava Bílý b. 1																	
4	Bradava 2	38	58					2	1							4	2829	30
5	Bradava 3	33	52													2	1700	25
6	Červený b. 1																	
7	Červený b. 2					10										1	500	6
8	Červený b. 3			12		5										2	680	20
9	Červený b. 4	14		3	8	4				2						5	886	33
10	Jalový brook																	
11	Klabava 1	7	342	14	18									1		5	21222	102
12	Klabava 2	20	221	7												3	6200	34
13	Klabava 3	37	95	1						2						4	3375	50
14	Klabava 4	129	46													2	1683	28
15	Klabava 5	107	51													2	1680	21
16	Kotelský b. 1	7														1	700	8
17	Kotelský b. 2	50														1	2000	30
18	Kotelský b. 3	5	90		17			4				1				5	5850	43
19	Ledný brook 1	23	15													2	1520	13
20	Ledný brook 2	45	49													2	3760	20
21	Ledný brook 3	19	14			2		4								4	1300	9
22	Litavka 1					20										1	1267	16
23	Litavka 2			19												1	800	3
24	Mitovský b. 1	1														1	40	1
25	Mitovský b. 2	2		3	12		2									4	575	11
26	Mitovský b. 3	7	2	1			2									4	343	11
27	Mourový brook	21														1	1050	36
28	Obecnický b. 1																	
29	Obecnický b. 2	59		2									2		1	4	2560	42
30	Obecnický b. 3	65		4				5		1	1					5	1900	82
31	Inflow Octárna																	
32	Pilský brook 1			5												1	333	13
33	Pilský brook 2	23														1	1917	39
34	Pstruh. – Oh. b. 1																	
35	Pstruh. – Oh. b. 2	15				1										2	889	25
36	Pstruh. – Oh. b. 3	27				13										2	2667	39
37	Pstruh. – Oh. b. 4	38				3										2	1367	17
38	Skořický brook 1	1	51													2	2080	10
39	Skořický brook 2	38	43	26												3	3567	21
40	Skořický brook 3	43	10			62		12								4	4233	21
41	Smolivecký b. 1	6														1	300	5
42	Smolivecký b. 2	28														1	1400	32
43	Smolivecký b. 3	33	10													2	1075	28
44	Vlčí brook 1	1														1	50	1
45	Vlčí b. 2 (75m)	8	21			3		2					1			5	2593	8
46	Závišínský b. 1	7	16													2	2300	20
47	Závišínský b. 2	7	22													2	2417	22
48	Závišínský b. 3	22	20	1												3	1720	28

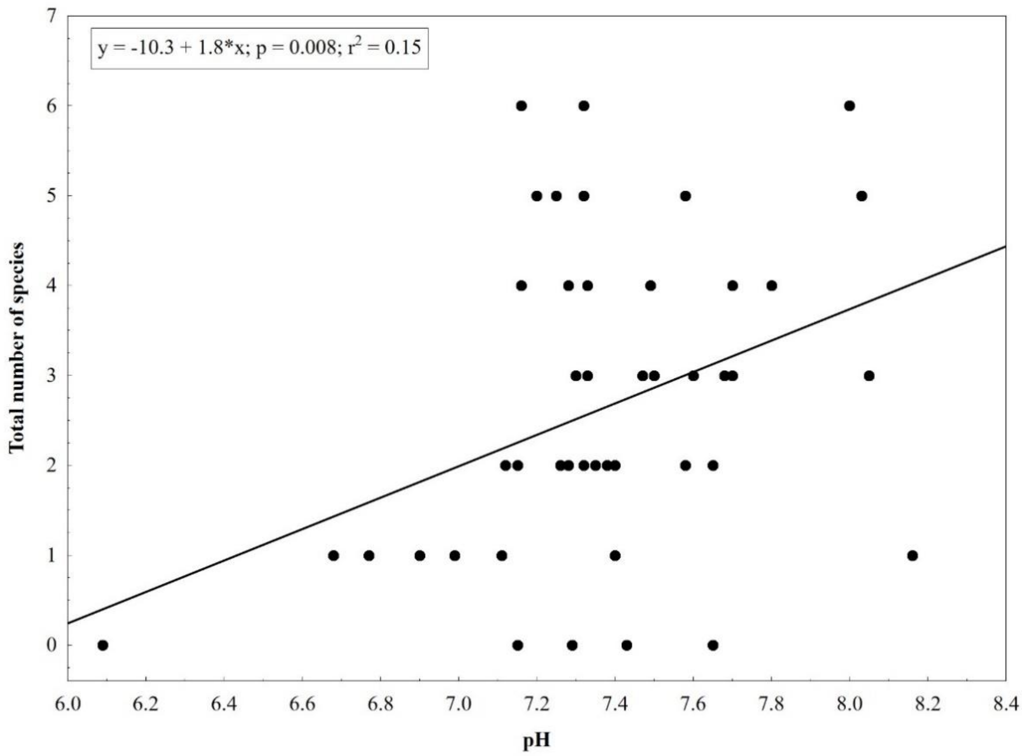

Figure 11 The effect of pH on fish species diversity.

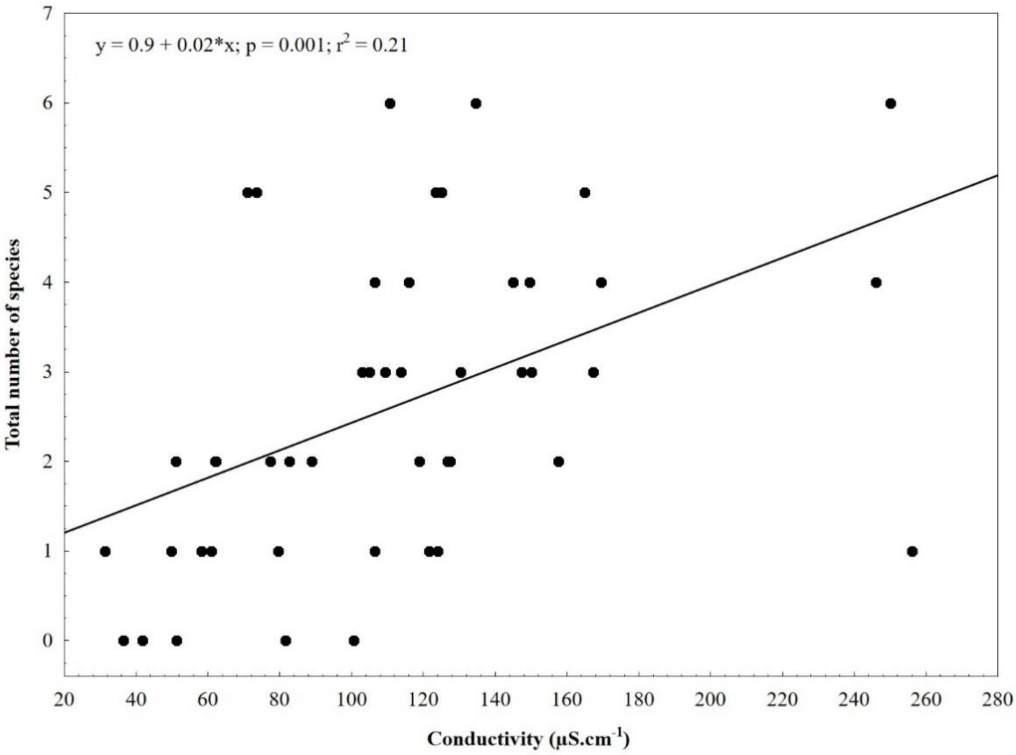

Figure 12 The effect of conductivity on fish species diversity.

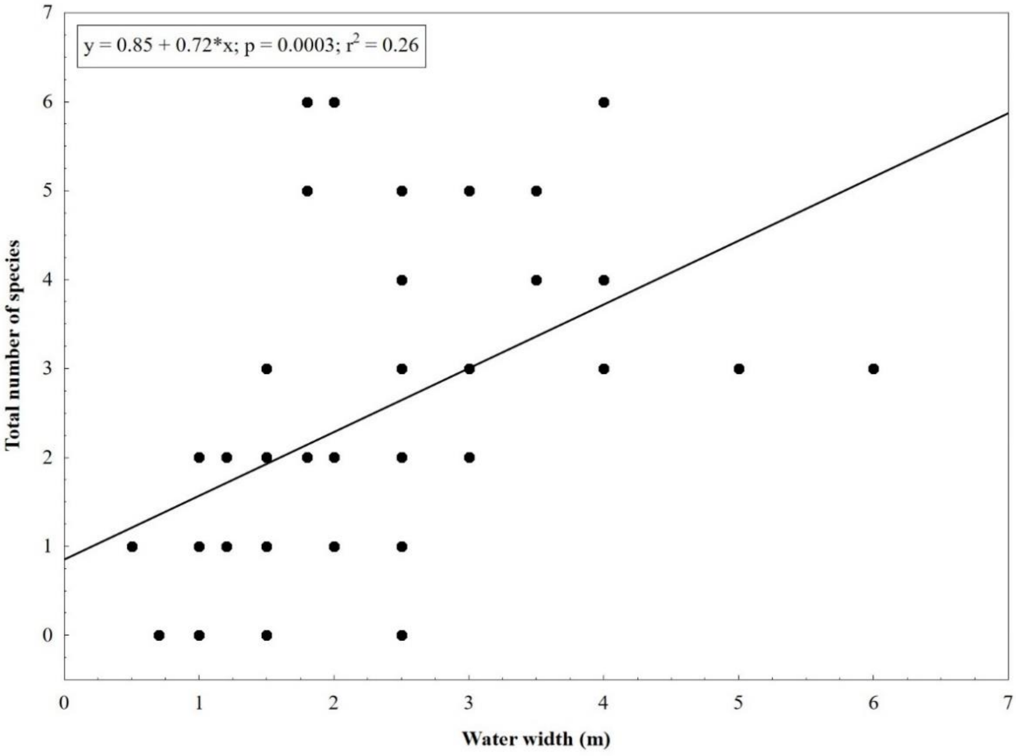

Figure 13 Effect of water width on fish species diversity.

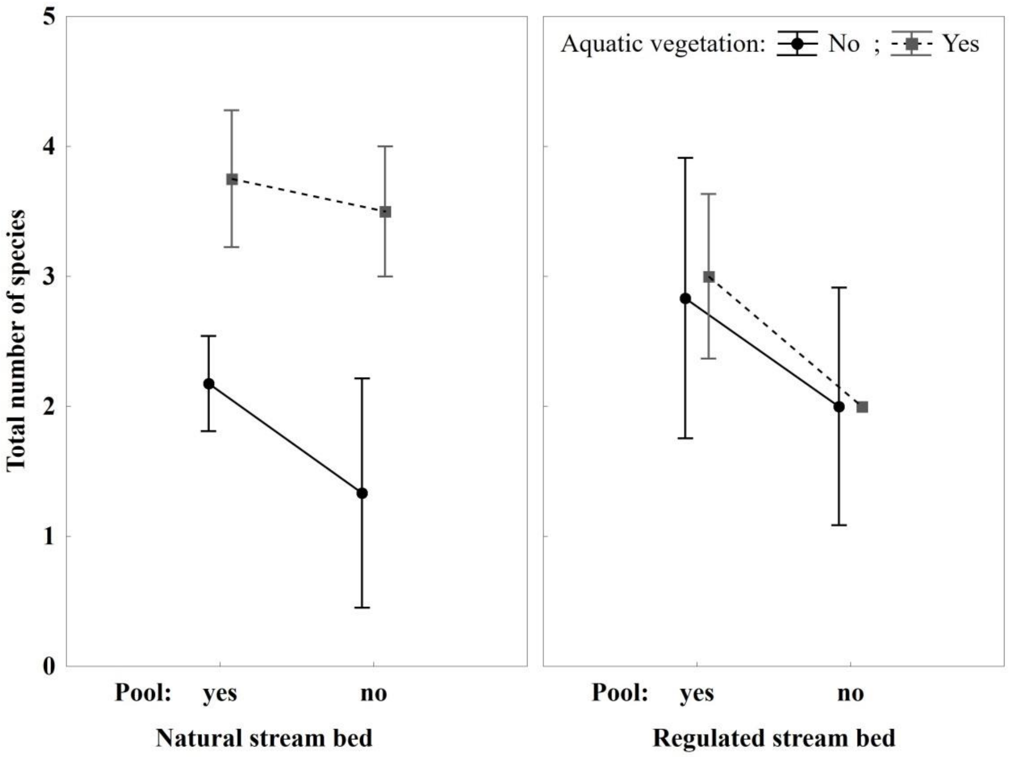

Figure 14 Relationship between type of stream bed, presence of aquatic vegetation, presence of pools and the species diversity. Vertical bars indicate ± SE.

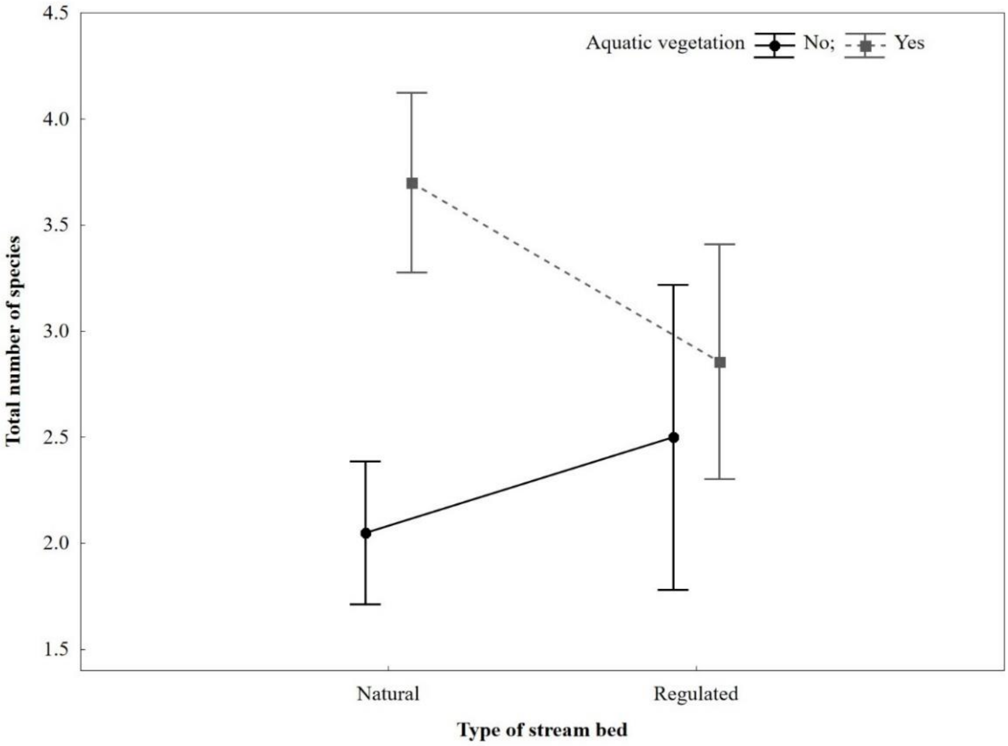

Figure 15 Relationship between type of stream bed, presence of aquatic vegetation and the species diversity. Vertical bars indicate ± SE.

4.3 Fish abundance

The most numerous species was Bullhead (1,095 recorded individuals) and then Brown trout (875 recorded individuals). Hereupon, the locality with the highest fish abundance was Klabava (6,832 individuals per hectare).

Range of total fish abundance on profile per hectare varied from 40 to 21,222.2 individuals per hectare with the mean 2,279 (± 523 SE). Quantitative parameters pH ($r^2 = 0.07$, $p = 0.09$), conductivity ($r^2 = 0.01$, $p = 0.5$) and water width ($r^2 = 0.02$, $p = 0.4$) resulted in very low explained variability by the applied regression models (r^2), therefore their influence on fish abundance was not proved. The abundance of fish was not affected by the type of stream bed ($F_{(1, 39)} = 1.7$, $p = 0.2$), neither by the presence of pools ($F_{(1, 39)} = 0.4$, $p = 0.53$) or by aquatic vegetation ($F_{(1, 39)} = 1.8$, $p = 0.2$) (Figure 16).

Nevertheless, in regulated and natural streams separately the effect of aquatic vegetation on fish abundance was different (Figure 17), i.e. when the stream bed was regulated, the fish abundance on a profile was similar even with or without aquatic vegetation, while in natural streams the fishes were more abundant when aquatic vegetation was present ($F_{(1, 37)} = 4.6$, $p = 0.04$).

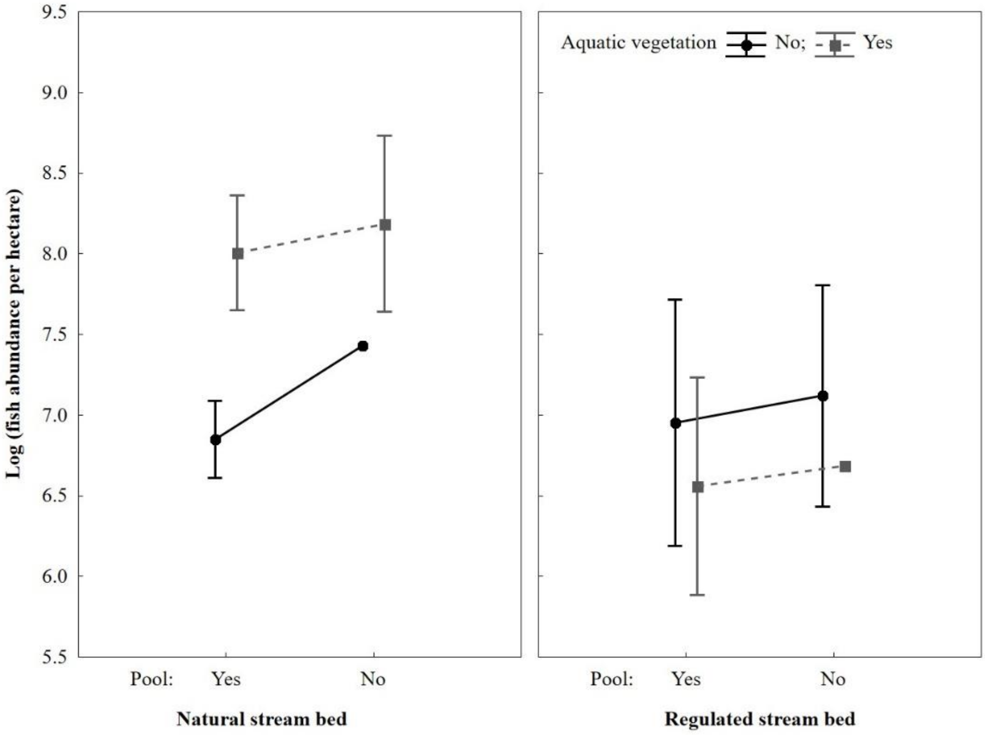

Figure 16 Relationship between type of stream bed, presence of aquatic vegetation, presence of pools and fish abundance. Vertical bars indicate ± SE.

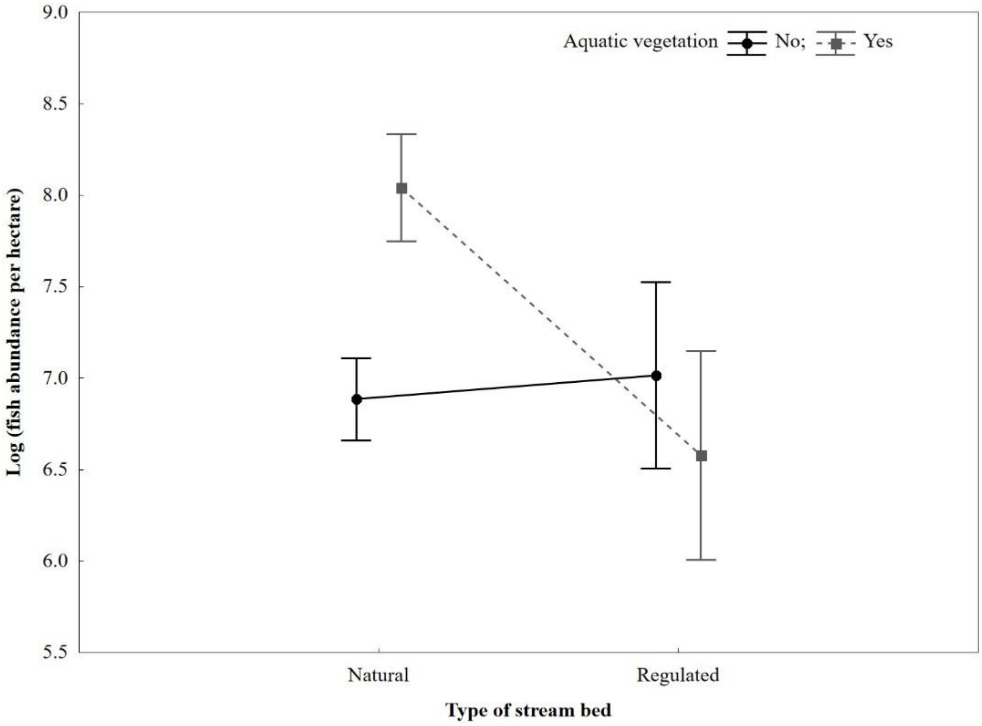

Figure 17 Relationship between type of stream bed, presence of aquatic vegetation and the total abundance per hectare. Vertical bars indicate ± SE.

4.4 Fish biomass

The locality with the highest fish biomass was Klabava (average biomass was 47 kg. ha^{-1}). Total fish biomass per hectare span varied from the 0.7 to 101.6 kg. ha^{-1} with the mean 24.6 kg. ha^{-1} (± 3.1 SE). The relationship between total fish biomass and total number of individuals showed positive correlation ($r^2 = 0.48$, $p < 0.01$) (Figure 18). There was no effect of pH, conductivity and water width on the fish biomass (all p values > 0.05). On the streams with natural stream bed was higher biomass while there was also present pools and aquatic vegetation. In the perspective of regulated streams, the higher biomass occurred when there was no aquatic vegetation, but the pools were present (Figure 19). However, this effect was not statistically supported as all p values were > 0.05.

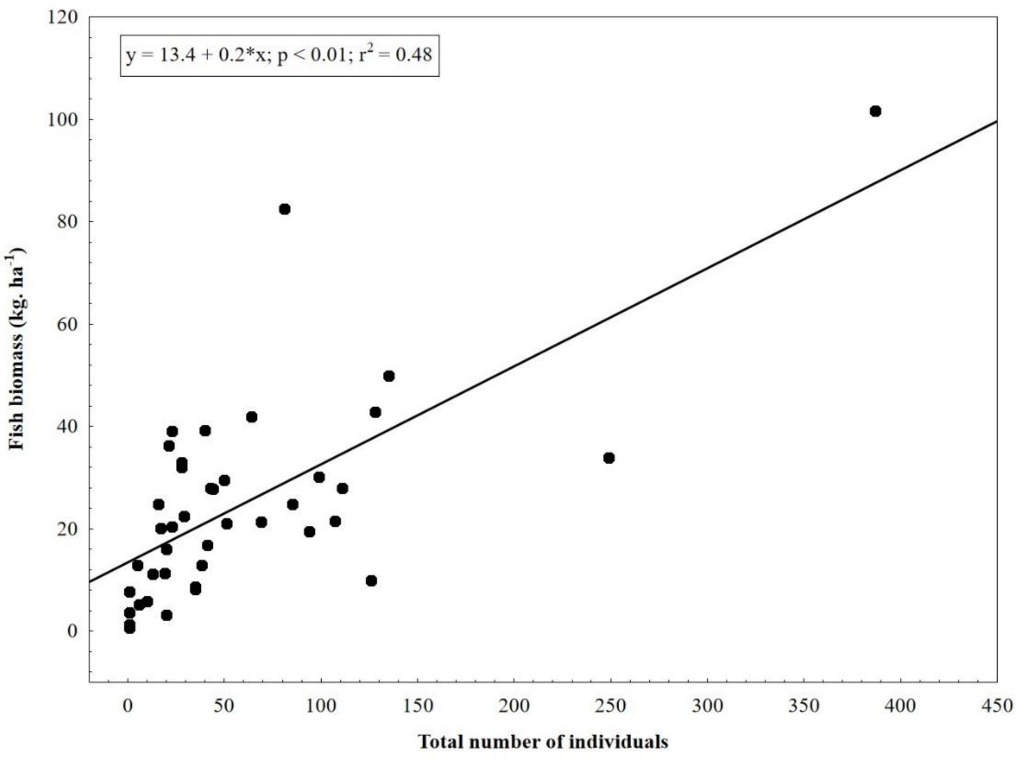

Figure 18 Relationship between total fish biomass (kg. ha^{-1}) and total number of individuals per profile.

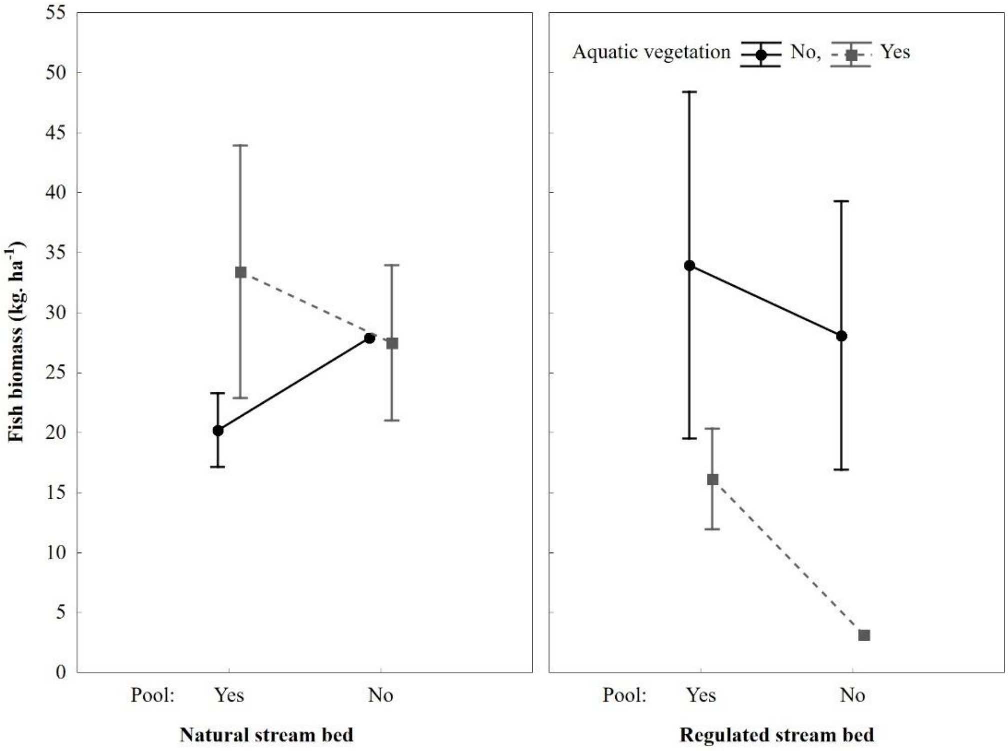

Figure 19 Relationship between total fish biomass (kg. ha^{-1}), type of stream bed, presence of aquatic vegetation and pools. Vertical bars indicate ± SE.

4.5 Fish age

There were identified five age groups of Brown trout and European perch (0+, 1+, 2+, 3+, 4+) and four age groups of Eurasian minnow and Common roach (0+, 1+, 2+, 3+). Overall composition of numbers of selected species and individual age categories (Figure 20) and also composition of numbers of individuals from age groups on certain localities for Brown trout, Eurasian minnow, European perch and Common roach (Appendix 1 to 4) were created Furthermore, age groups frequency pie charts were compiled (Figure 21).

Influence of qualitative environmental parameters on age of brown trout (*Salmo trutta*) was proved quite significant (type of stream bed ($F_{(1, 285)} = 4.6$, $p = 0.03$), presence of pools ($F_{(1, 285)} = 8.2$, $p = 0.004$) and presence of aquatic vegetation ($F_{(1, 285)} = 9.3$, $p = 0.003$). Further, there was confirmed presence of 114 individuals of brown trout in regulated stream bed with average age 1+ (± 0.1 SE). Moreover, the number of individuals was higher in natural stream bed (N = 175) with the same age 1+ (± 0.1 SE). In case of the presence of pools, where there were some, the number increased to 238 individuals of brown trout with average age 1+ (± 0.1) and where there were not any, the number of individuals was 51 Brown trouts with average age 2+ (± 0.2 SE). As for the presence of aquatic vegetation, the average age was 1+ (± 0.2 SE) of 96 Brown trouts when there was aquatic vegetation, however the number of individuals was higher when there was not any aquatic vegetation (N = 193) with average age 1+ (± 0.1 SE). The total average age was 1 + out of 289 individuals of brown trout (± 0.1 SE). Overall charts for age group composition on selected localities was created (Appendix 1).

Effects of qualitative parameters on the Common perch (*Perca fluviatilis*) were proved significant only when speaking of the presence of aquatic vegetation ($F_{(1, 51)} = 6.1$, $p = 0.02$). If there was some aquatic vegetation, the average age was 1+, but only for 20 individuals (± 0.1 SE) and if there was not any, the average age was also 1+ but for higher number of individuals (N = 35, ± 0.2 SE). The type of stream bed ($F_{(1, 51)} = 0.001$, $p = 0.2$) and presence of pools ($F_{(1, 51)} = 1.8$, $p = 0.98$) was not statistically confirmed as significant effect. The total average age was 1 + out of 55 individuals of common perch (± 0.1 SE).

The total average age of Eurasian minnows (*Phoxinus phoxinus*) was 0+ (± 0.2 SE) out of 41 individuals. This species was present only in the streams with natural stream bed. There was found effect of environmental qualitative parameter, the presence of aquatic vegetation ($F_{(1, 39)} = 24.4$, $p = 0.0002$). Subsequently, it was ascertained that the Eurasian minnows were either in the streams with aquatic vegetation but no pools or rather in the streams with no aquatic vegetation, but with pools. Average age in the streams with aquatic vegetation but no pools was 0+ (N = 30, ± 0.1 SE) and conversely the average age was 1+ (N = 11, ± 0.3 SE).

Lastly, Common roach (*Rutilus rutilus*) was present only in the streams with pools (N = 42). The effect of the type of stream bed ($F_{(1, 39)} = 0.005$, $p = 0.9$) was not significant. Presence of aquatic vegetation was significant ($F_{(1, 39)} = 49.9$, $p < 0.01$). Number of the individuals present in streams with natural stream bed was 32 with average age 1+ (± 0.2 SE) and in streams with regulated stream bed was the average age also 1+ out of 10 individuals (± 0.3 SE). As for presence of the aquatic vegetation, in case there was some, the average age was 1+ (N = 34, ±

0.1 SE) and when there was not any, the average age was 3+ (N = 8, ± 0.2 SE). The total average age was 1 + out of 42 individuals of common roach (± 0.2 SE).

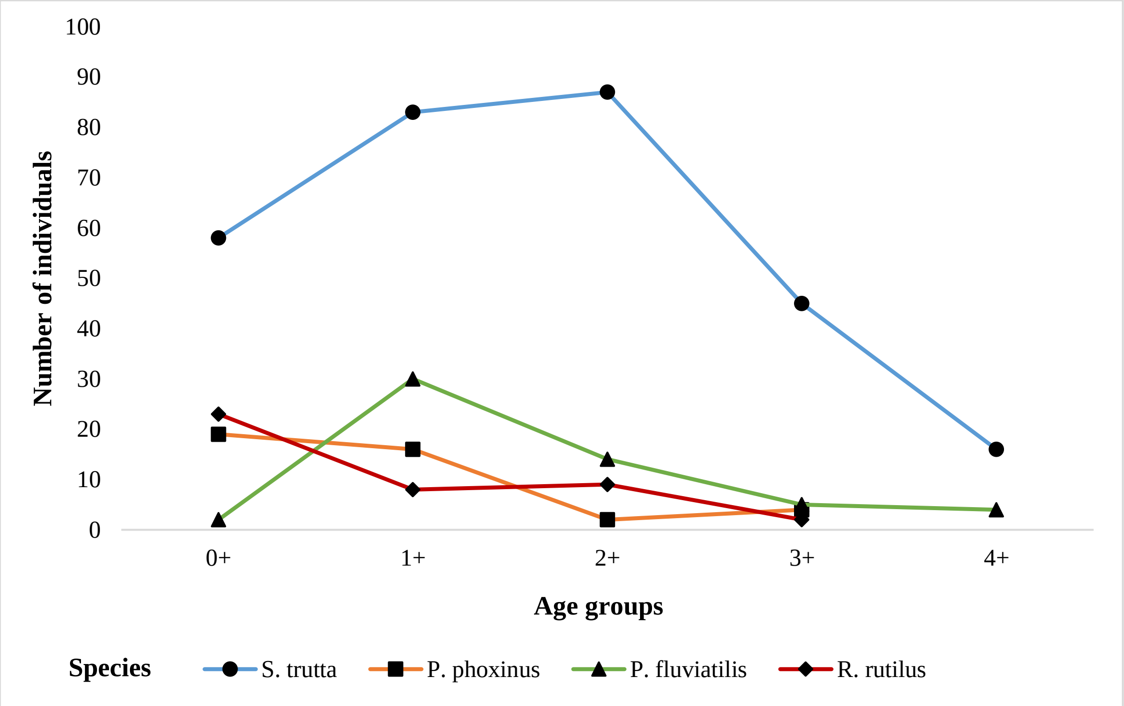

Figure 20 Numbers of individuals of each age group of selected species from selected age sample.

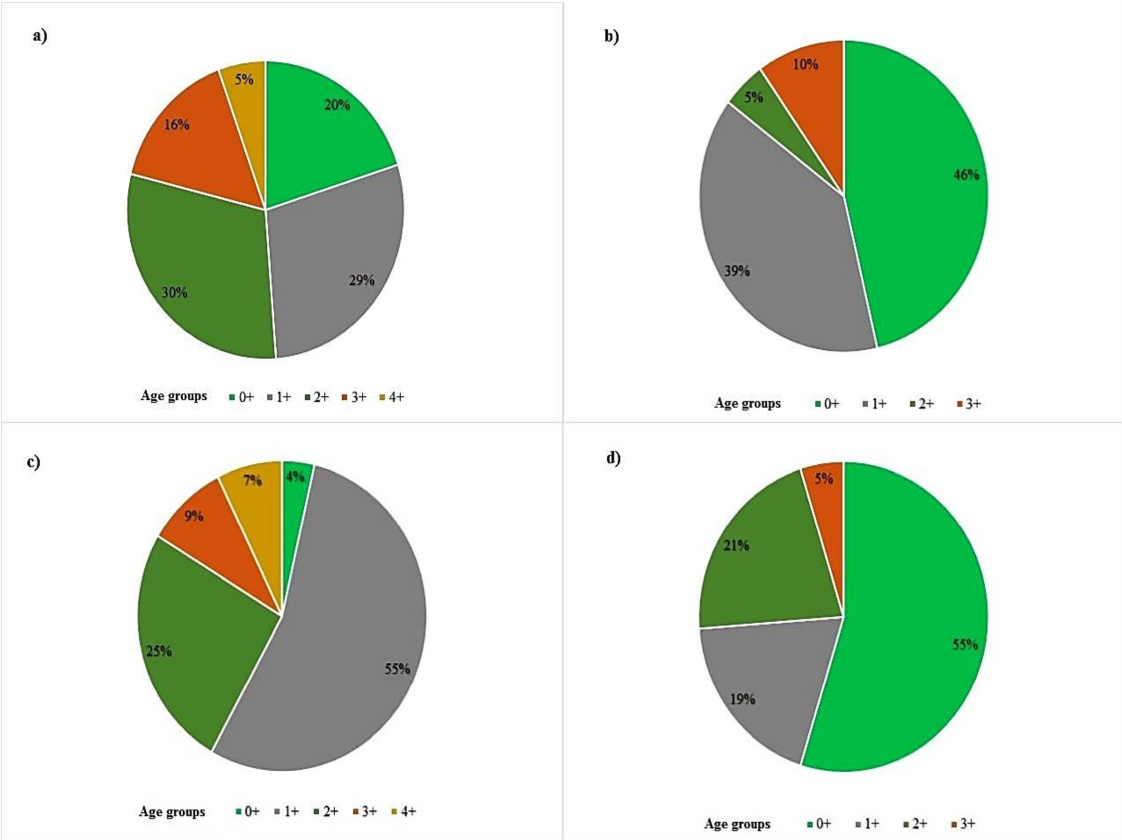

Figure 21 Frequency of age groups of: a) Brown trout, b) Eurasian minnow, c) Common perch and d) Roach.

4.6 European brook lamprey (*Lampetra planeri*) in focus

From all 48 surveyed profiles, there were found records of total 325 individuals of European brook lamprey on 20 profiles altogether. Distribution and total abundance of this species were determined (Table 6). Comparison of recorded individuals from 2000 and 2016 was created (Figure 22). Also, length span structure of surveyed individuals on selected profile was assessed (Figure 23) and average length was 71 cm (± 2 SE).

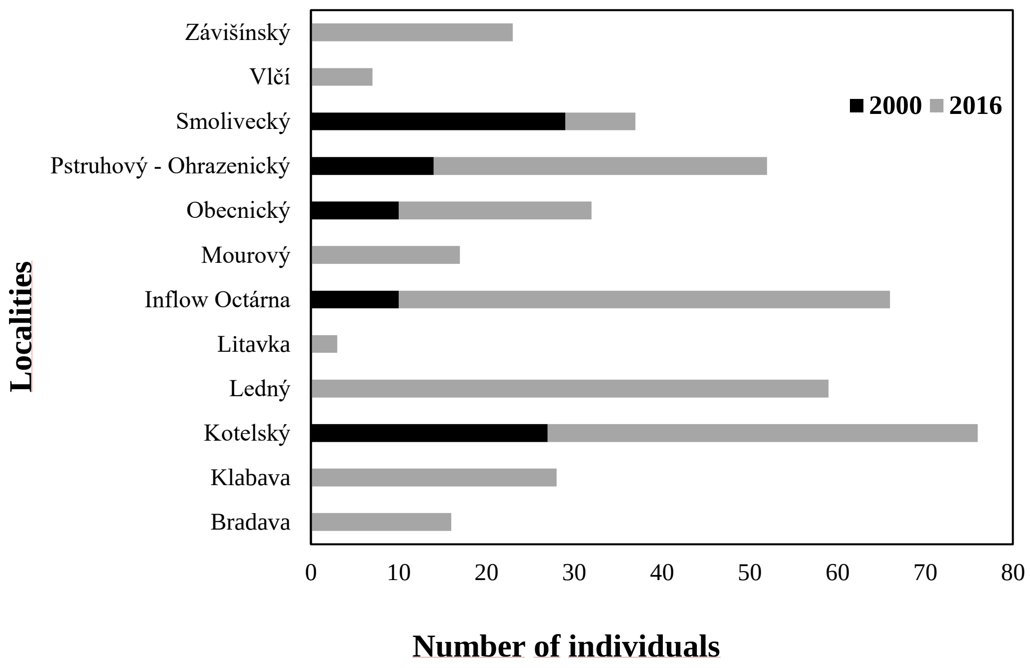

Figure 22 Number of European brook lamprey (*Lampetra planeri*) in 2000 and in 2016 on stream localities.

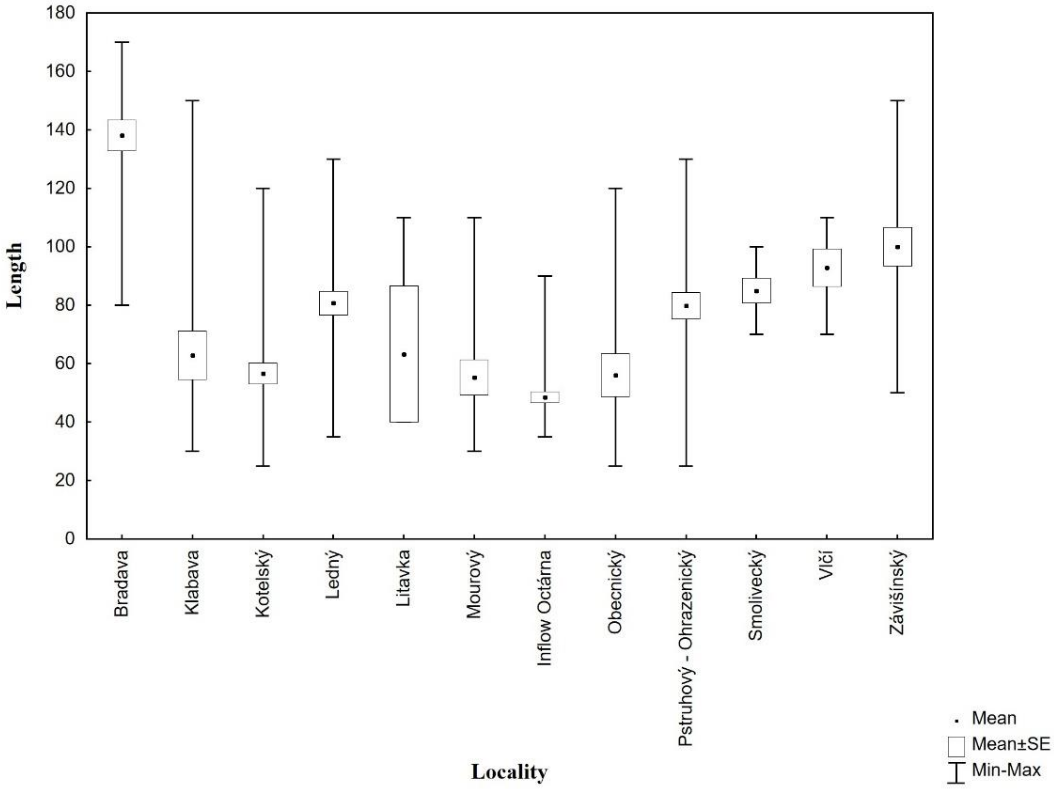

Figure 23 Span of length variability of European brook lamprey (*Lampetra planeri*) on stream localities.

Table 6 Distribution and total abundance on profile of European brook lamprey (*Lampetra planeri*).

	Species	**Number of *L. planeri***	**Total abundance of *L. planeri* per m²**
ID	**Profile**		
1	Albrechtský brook		
2	Inflow – Hořejší Padrťský pond		
3	Bradava Bílý brook 1		
4	Bradava 2	1	2
5	Bradava 3	15	5
6	Červený brook 1		
7	Červený brook 2		
8	Červený brook 3		
9	Červený brook 4		
10	Jalový brook		
11	Klabava 1		
12	Klabava 2		
13	Klabava 3		
14	Klabava 4	13	3
15	Klabava 5	15	10
16	Kotelský brook 1		
17	Kotelský brook 2	44	29
18	Kotelský brook 3	5	2
19	Ledný brook 1	23	8
20	Ledný brook 2	22	11
21	Ledný brook 3	4	2
22	Litavka 1		
23	Litavka 2	3	3
24	Mitovský brook 1		
25	Mitovský brook 2		
26	Mitovský brook 3		
27	Mourový brook	27	27
28	Obecnický brook 1		
29	Obecnický brook 2	19	6
30	Obecnický brook 3	3	2
31	Inflow Octárna	56	28
32	Pilský brook 1		
33	Pilský brook 2		
34	Pstruhový – Ohrazenický brook 1		
35	Pstruhový – Ohrazenický brook 2		
36	Pstruhový – Ohrazenický brook 3	5	3
37	Pstruhový – Ohrazenický brook 4	33	11
38	Skořický brook 1		
39	Skořický brook 2		
40	Skořický brook 3		
41	Smolivecký brook 1		
42	Smolivecký brook 2	4	3
43	Smolivecký brook 3	3	3
44	Vlčí brook 1		
45	Vlčí brook 2 (75m)	7	7
46	Závišínský brook 1		
47	Závišínský brook 2		
48	Závišínský brook 3	23	8

4.7 Comparison of populations in 2000 and 2016

Numbers of certain fish species in 2000 and in 2016 was compared. As for these numbers, there were differences, but not statistically supported ($F_{(14, 48)} = 1$; $p > 0.05$) (Figure 24). Since the small amount of data, concrete changes of certain species are only shown in line chart (Figure 25).

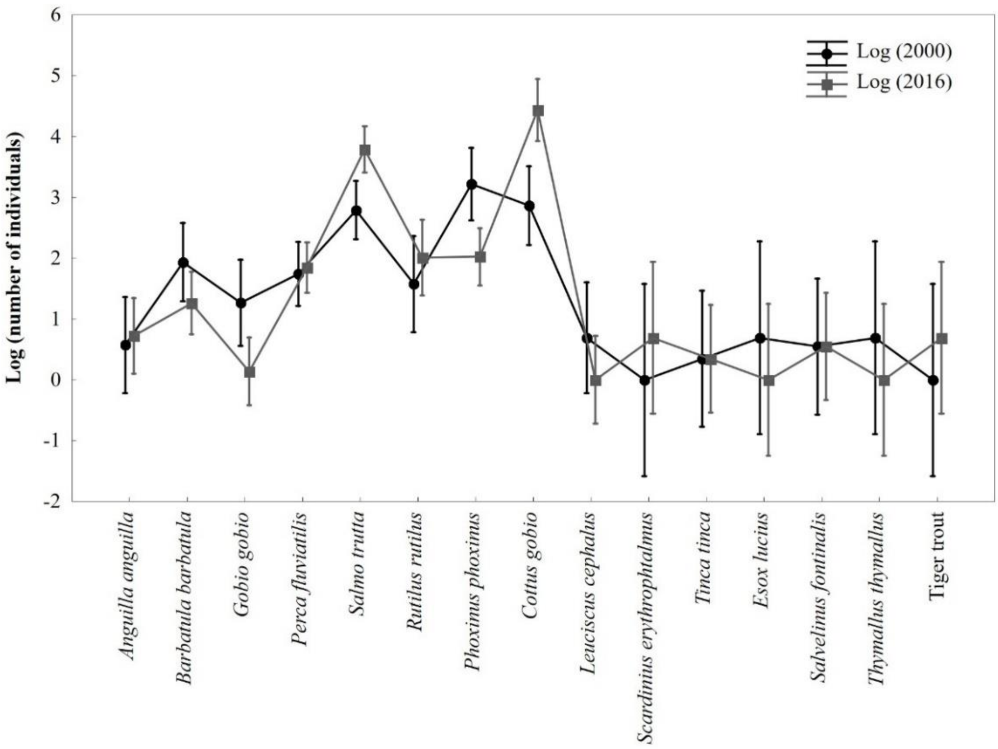

Figure 24 Numbers of individual species in 2000 and in 2016. Vertical bars indicate ± SE.

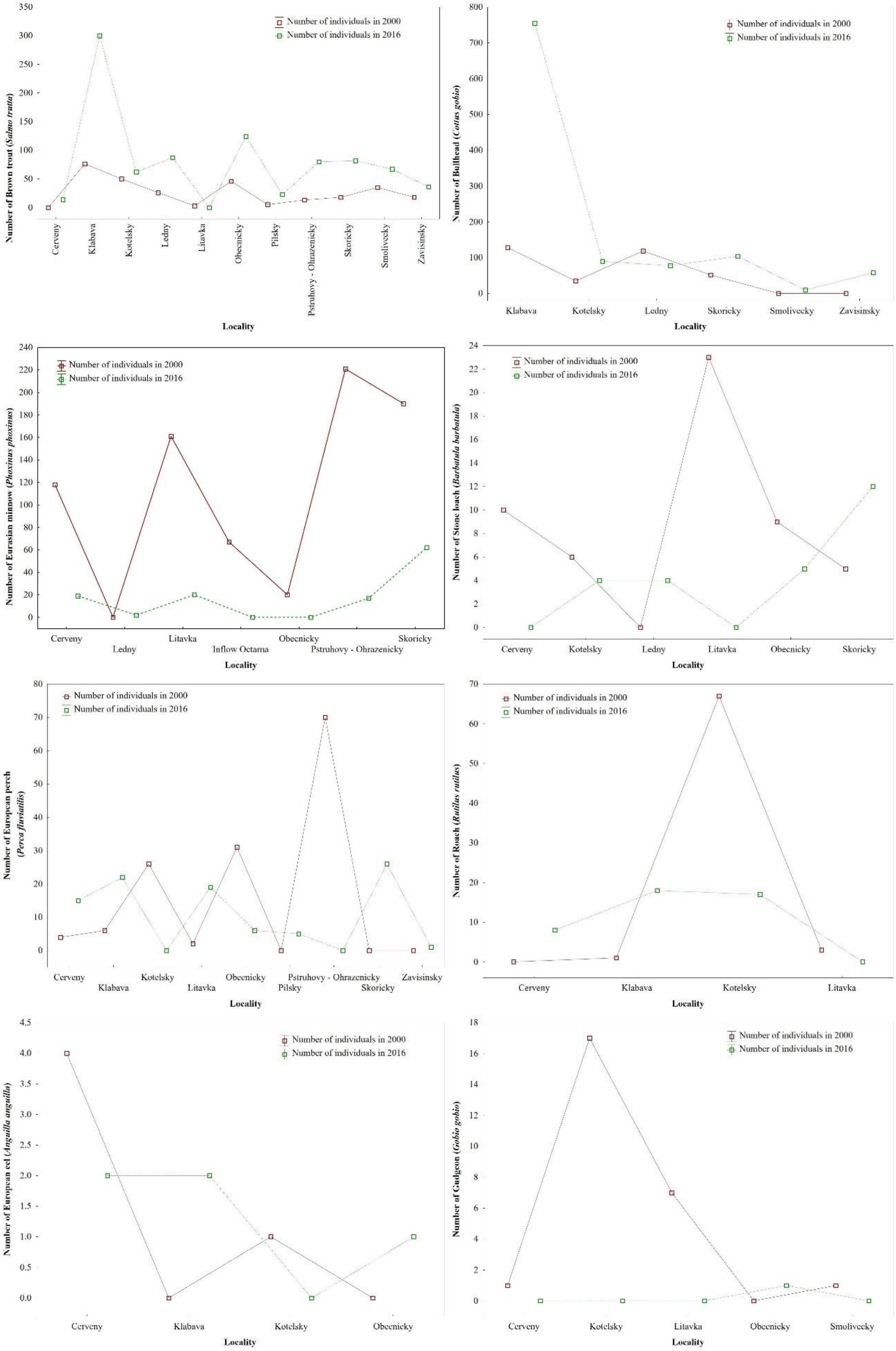

Figure 25 Numbers of surveyed species in 2000 and in 2016 on selected profiles (a) Brown trout, b) Bullhead, c) Eurasian minnow, d) Stone loach, e) European perch, f) Common roach, g) European eel, h) Gudgeon).

5 Discussion

Environmental variables in streams in the PLA Brdy showed different effects on tested parameters. Concretely, the range of pH in surveyed water profiles was from 6.1 to 8.2 and corresponding to tolerable pH for fish species from 6.5 to 8.5 (Adámek, 1992; Máchová and Kouřil, 1992; Vykusová, 1992; Svobodová, 1992). The only profile which was not fitting to this statement, was the first profile of Červený brook. Probably, for this reason, there were no fish species recorded. Moreover, our results of 48 surveyed profiles as there was low or no influence of pH on fish species diversity, fish abundance and fish biomass, do not completely support the statement of AOPK (2012), that the occurrence of fishes and other water organisms in Brdy PLA is nowadays influenced and restricted mainly by low pH in some streams or their parts. The major reason of low fish species diversity and fish abundance in some profiles would be the fact, that these profiles were in higher altitudes since the results showed that fish abundance and fish biomass conditions of surveyed profiles correspond with the fish abundance and fish biomass characteristics. (Adámek, 1997; Kubečka, 2014). Moreover, the low species abundance in stream networks which drainage higher and slanting parts could be also caused by the lack of precipitation from August to winter months (AOPK ČR, 2012). Furthermore, the study confirmed low effect of conductivity on fish species diversity, fish abundance and fish biomass when the range of measured conductivity was within limits (Horne and Goldman, 1994; U.S. E.P.A., 2017). Also, it was confirmed that the species diversity increases with the size of the area, thus with the water width, since the water profiles had the same length (Preston, 1962). From the qualitative aspect, the dominating profiles were the ones with natural type of stream bed, from all the surveyed profiles. Further analysis showed that the type of the stream bed had no effect on fish species diversity or fish biomass. But, the result of effect of natural stream bed and presence of aquatic vegetation on fish abundance was significant and the streams were more abundant which confirms the study concerning the occupation of fishes of aquatic vegetation (Rozas and Odum, 1988) and the statements of Eklöv (1997) and Slavík (2014), that water environment rich in shelters enables the higher fish abundance and flows with the stream bed shaped by natural flow effect, spontaneous sedimentation, occurrence of submerge aquatic vegetation and dead wood materials represents water environment with optimal level of shelters. On the contrary, channelized and regulated flows with fortified banks and shorelines and with straightened stream beds, provides shelters on minimal level. Aquatic vegetation was only in 17 profiles from the total 48 profiles. Species diversity was higher in profiles with aquatic vegetation as well. Pools were present in 37 profiles but there was no significant effect on fish species diversity, fish abundance and fish biomass so that stated relationship were not confirmed (Lellák and Kubíček, 1992; Ambrožová, 2003). The qualitative parameters showed certain effect on fish age groups of selected species. From our results it seems, that one year old individuals of Brown trout were present in higher numbers in natural stream bed. On the other hand, numbers of one year old individuals of Brown trout were lower when the aquatic vegetation was present. Also, it seems that they also preferred parts with pools where was the number higher as well. One year old European perches were more abundant in parts with aquatic vegetation. Eurasian minnows were present only in streams with natural stream bed. This year minnows were more abundant in profiles with aquatic vegetation but no pools. On the other hand, the one year old minnows were more abundant in profiles without aquatic vegetation but with pools. Common roach was present only in profiles with pools. The one year old roaches were more abundant in profiles with aquatic vegetation. Where there was no aquatic vegetation, there were present only three years old roaches. Also, the age distribution of four species (Brown trout, Eurasian minnow, European perch and Common roach) showed, that the greatest age diversity of Brown trout (from 289 individuals) was on Klabava. The highest number of year trouts was present on Kotelský, Ledný and Skořický brook, of one year old trouts was on Klabava, Obecnický, Pilský, Pstruhový – Ohrazenický brook, of two years old trout was on Bradava, Kotelský, Mourový and Smolivecký brook and the highest number of three years old trouts was on Mítovský and Červený brook (Appendix 1). As for Eurasian minnow, the fish scales were taken only from fish present on Skořický brook (this year and one year old minnows, with the dominance of this year old minnows) and on Červený brook (Appendix 2). The highest number of one year old European perches was on Klabava, Mítovský and Skořický brook, of two years old was on Mítovský, Obecnický and Červený brook (Appendix 3). The highest number of one year old Common roaches was on Klabava, Kotelský and Mítovský brook and three years old roaches were most abundant on Červený brook (Appendix 4). For further research of age structure and the influence of environmental factors, another survey should be done in future. Nevertheless, studies examining aquatic assemblage patterns associated with environmental variability, resource levels, as well as a spatial component in a synthetic manner are still needed to characterize the relative importance of these factors (Niu and Knouft, 2017). Lastly, a description of protected and significant species - European brook lamprey showed that they occur on new localities (Figure 22). This fact possibly indicates long – term high quality of local environment on these localities, since the larvae of this species can serve as bio – indicators for such environment (Hanel et al., 2003; Hanel and Andreska, 2006). Average length of surveyed individuals of lamprey was 71 cm (± 2 SE). This species was more abundant on profiles with natural bed type which confirms the fact that inappropriate adjustment of beds is a limiting factor for occurrence of European brook lamprey (Gergel and Ehrlich, 2002; Hanel and Lusk, 2005). Statistical comparison of numbers of key species on certain localities in 2000 and in 2016 showed that there were differences, however not statistically significant (Figure 24). On the other hand, in case of Eurasian minnow, there were high population declines on streams Červený brook, Litavka, Pstruhový – Ohrazenický brook, Skořický brook and moreover, there were declines to no records on streams Inflow Octárna and Obecnický brook. Numbers of Brown trout increased on streams Klabava, Ledný brook, Obecnický brook. Bullhead very increased on Klabava. Stone loach highly decreased to zero individuals on Litavka, but newly occured on Ledný brook. European perch highly decreased on Pstruhový – Ohrazenický brook to no record, but in general together on all localities where the perch was present, the population was balanced. Very high decrease to zero individuals was on four localities from total five, where was Gudgeon naturally present in former times (all species charts see Figure 25). Decrease of several fish species as Eurasian minnow, Stone loach or Gudgeon could be explained as the result of fishery management. According to AOPK ČR (2012), the main threat to ichthyofauna is fishery management on ponds. Frequent problems are high amount of mud in flows after the releasing of the ponds and the flow – rate fluctuations while manipulating with the water level of the pond (Padrťský pond with the low pH and high amount of toxic metals). Another threat to local ichthyofauna are predatory fishes as European perch (*Perca fluviatilis*), which are indigenous to barbel and bream fish zone and do not belong to fish zone in Brdy PLA (Adámek, 1995; Kubečka, 2014). European perches, in this case, are intensively set into the ponds and water tanks and also massively reproduced there. As result, these predatory fishes restrict more important fish species directly in water tanks or penetrate to water flows and destroy local fish populations (e.g. Eurasian minnow (*Phoxinus phoxinus*)).

6 Conclusions

In conclusion, the most of measured environmental variables on 48 water profiles in the Brdy PLA played an important role on fish diversity and abundance. Water width had effect on fish species diversity. There was confirmed no effect of conductivity in valid limit range and low or no effect of pH on fish species diversity, fish abundance or fish biomass. Type of stream bed had no effect on fish species diversity and fish biomass. Presence of aquatic vegetation confirmed effect on species diversity. Presence of pools had no effect on fish species diversity, fish abundance and fish biomass. It was confirmed that all qualitative parameters (natural or regulated stream bed type, presence/absence of aquatic vegetation and presence/absence of pools) influenced certain age structures of selected species. Population of European brook lamprey (*Lampetra planeri*) was described and it was found that they occur on new localities which possibly indicates long – term high quality of local environment on these localities (Hanel et al., 2003; Hanel and Andreska, 2006). Comparing numbers of selected species on certain localities in 2000 and in 2016 showed differences, mainly declines of Eurasian minnows, Stone loach, and Gudgeon and increase of Brown trout and Bullhead, however not statistically significant. The further question and aim should be focused on possible change of the environment of Brdy PLA leveraged by fishery management, public and tourism since this area was protected so far from uncontrolled urbanisation, mass tourism, chemical products, and fertilizers causing general ruderalization and pollution of water flows (AOPK, 2017). Finally, it is always necessary to look onto the processes happening in water system from the whole environmental perspective to research the overall essence.

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The Appendices

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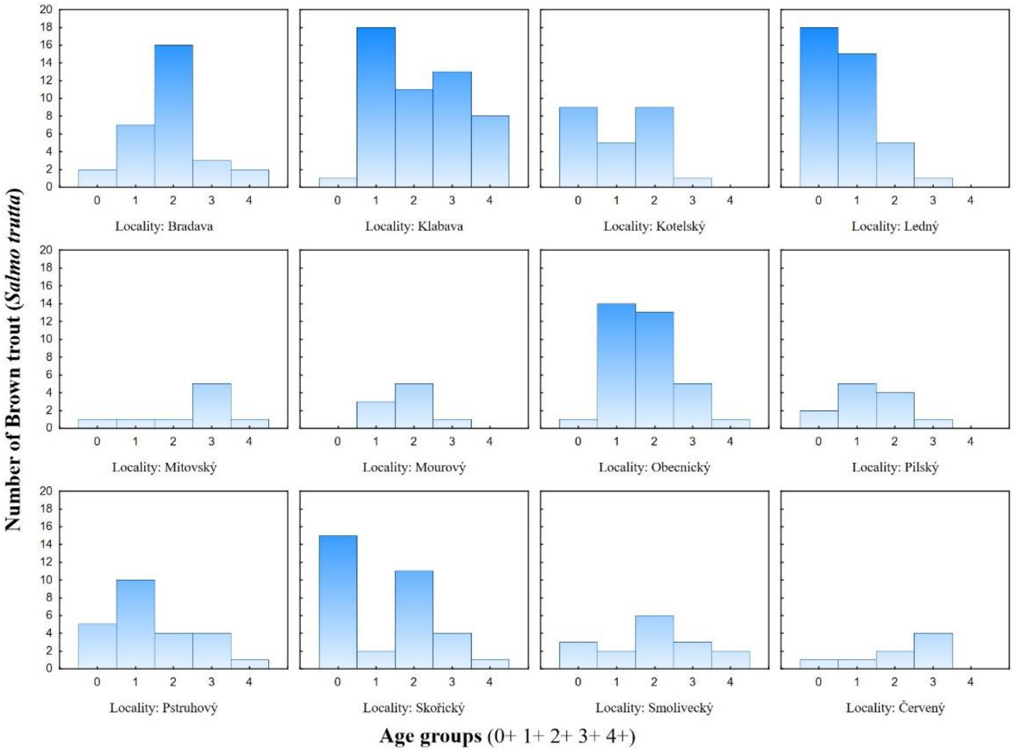
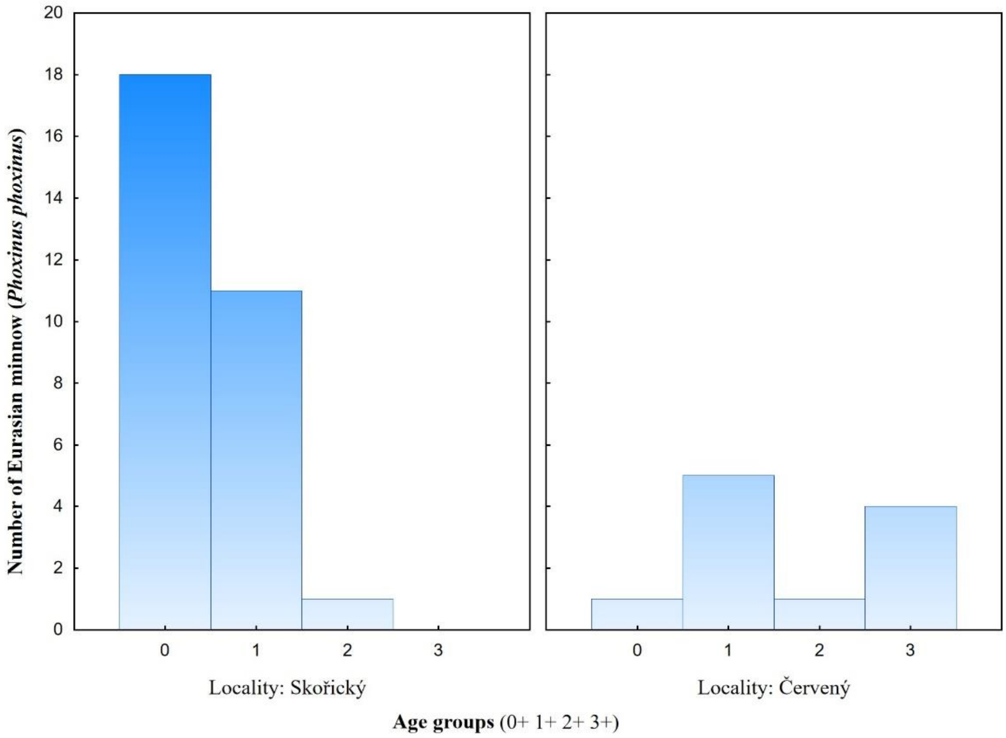
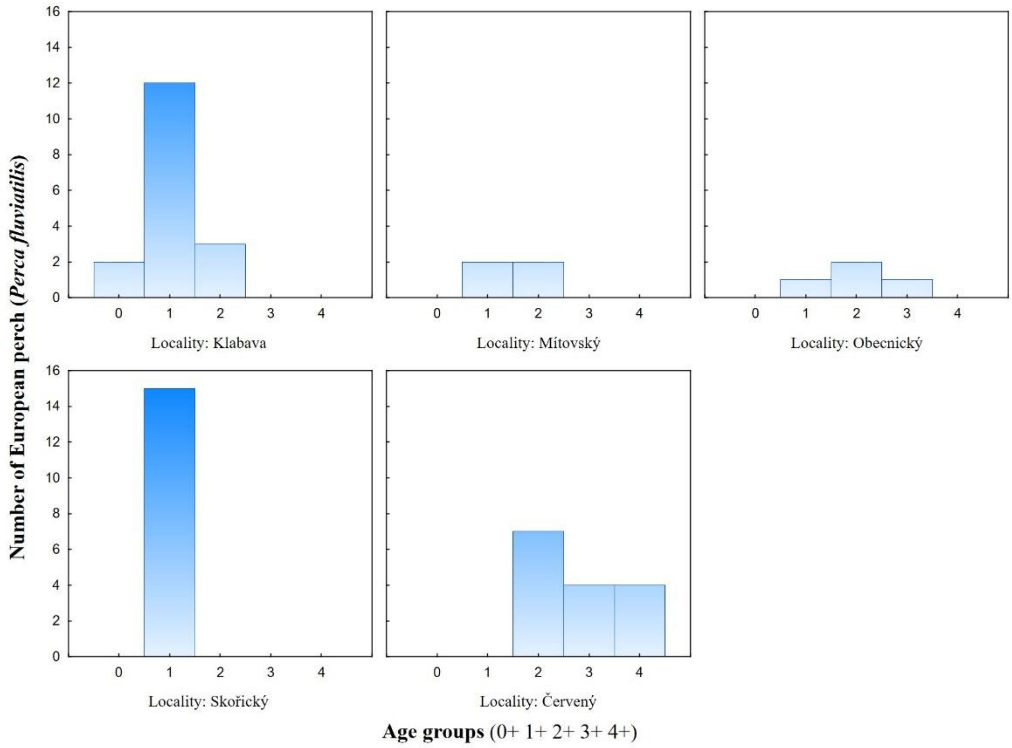


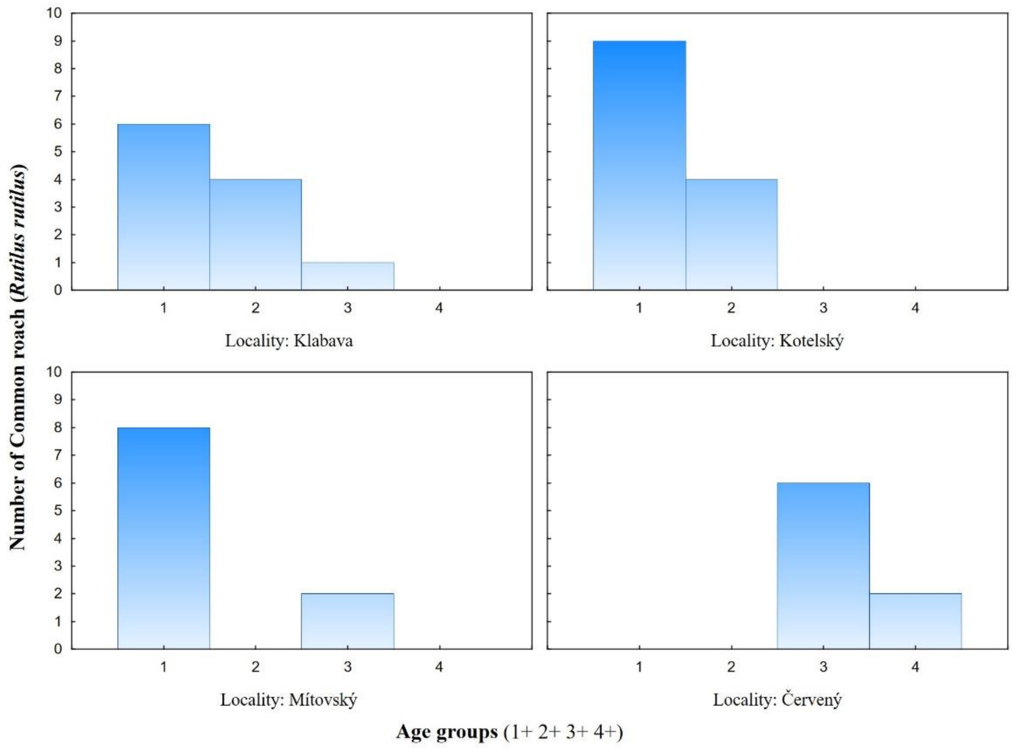
Appendix 1 Age groups of Brown trout (*Salmo trutta*) on selected localities.



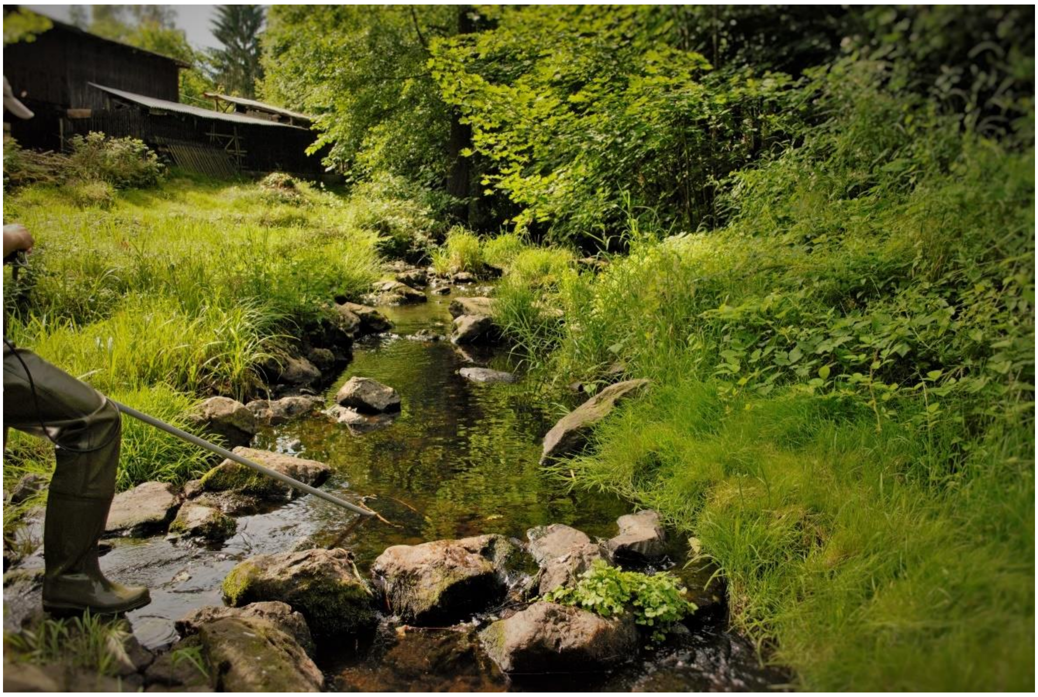
Appendix 2 Age groups of Eurasian minnow (*Phoxinus phoxinus*) on selected localities.



Appendix 3 Age groups of European perch (*Perca fluviatilis*) on selected localities.



Appendix 4 Age groups of Common roach (*Rutilus rutilus*) on selected localities.



Appendix 5 Illustration of the process of electrofishing (photo by A. Ťuláková, 2016).

Appendix 6 Illustration of measurements of length on Brown trout (photo by A. Ťuláková, 2016).

Appendix 7 Illustration of weighing on Brown trout (photo by A. Ťuláková, 2016).

Appendix 8 Illustration of the sampling of fish scales on Brown trout (photo by A. Ťuláková, 2016).

Appendix 9 European perch (*Perca fluviatilis*, photo by T. Caska, 2016)

Appendix 10 Common roach (*Rutilus rutilus*, photo by A. Ťuláková, 2016)

Appendix 11 Stone loach (*Barbatula barbatula*, photo by D. Fischer, 2016).

Appendix 12 Tiger trout (hybrid Brown trout (*Salmo trutta*) x Brook trout (*Salvelinus fontinalis)*, photo by D. Fischer, 2016).

Appendix 13 Illustrating picture of second profile of Klabava (photo by D. Fischer, 2016).

Appendix 14 Illustrating picture of second profile of Klabava (photo by T. Caska, 2016).